

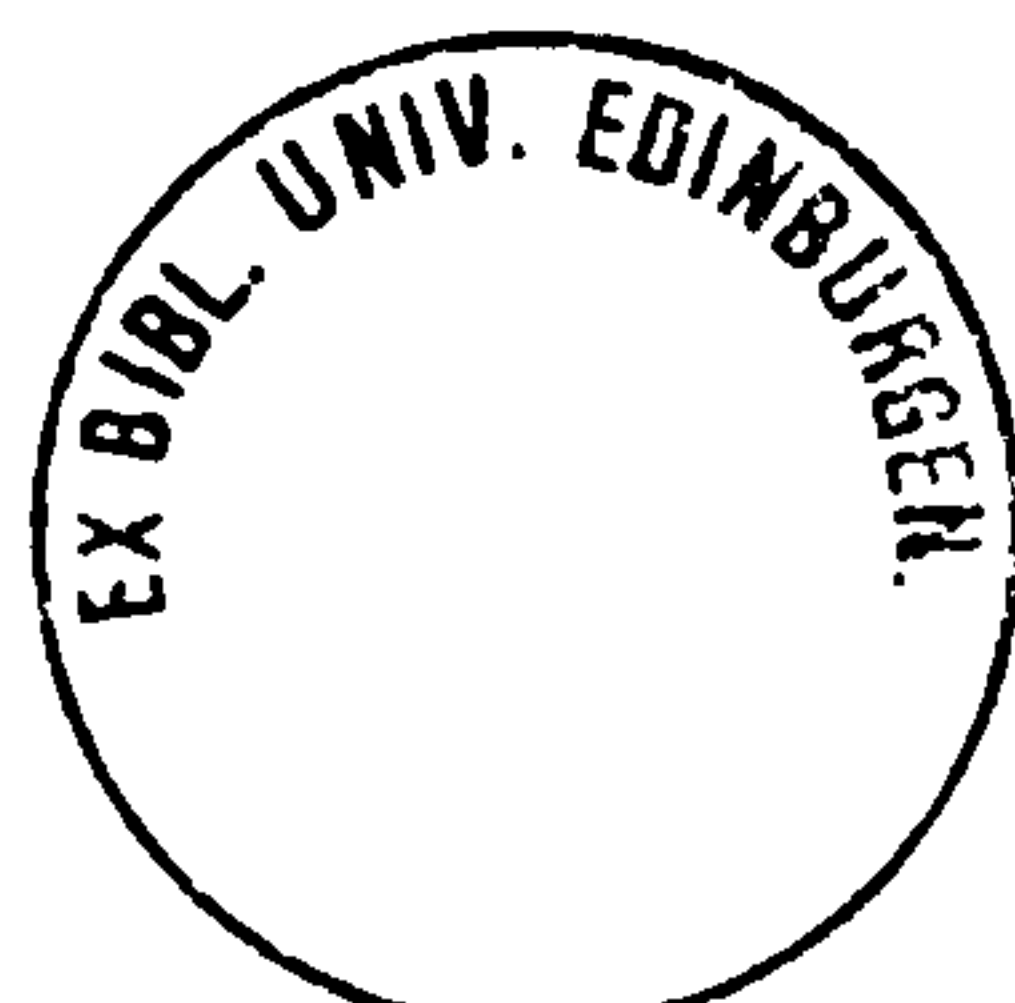
Tense, Aspect and Temporal Reference

Marc Moens

Ph.D.

University of Edinburgh

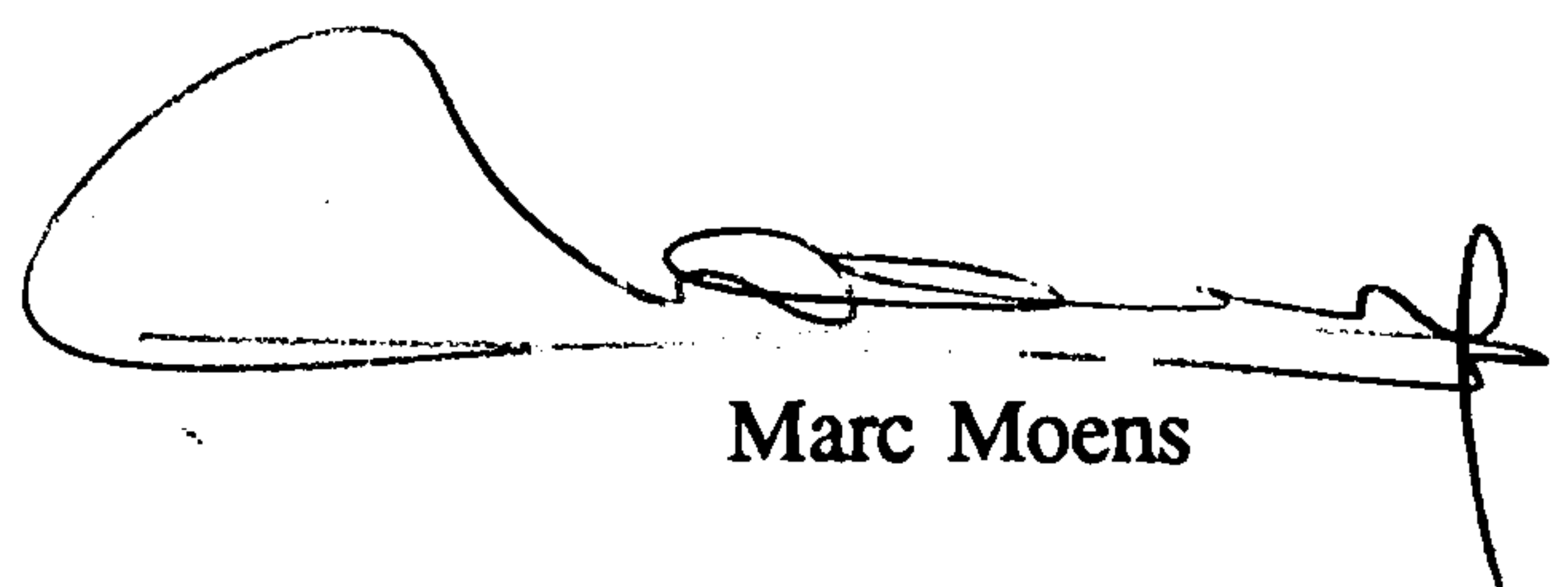
1987



Declaration

I declare that this thesis has been composed by myself and that the research reported therein has been conducted by myself unless otherwise indicated.

Edinburgh, September 15, 1987

A handwritten signature in black ink, consisting of a large, stylized loop followed by a series of smaller, connected strokes that end in a vertical line.

Marc Moens

Acknowledgements

Before I begin to tell my story, I would like to mention a number of people who have played an important part over the years it took me to complete this dissertation.

Mark Steedman, who suggested to me the topic of tense and aspect. I see myself forced by the rules of etiquette to thank him for this. There is probably no idea in this dissertation which I did not discuss with Mark - over lunch, dinner, drinks or during the many sessions in his office. And when times got really rough and nothing seemed to be going well, he fixed my car radio and said that everything else would sort itself out as well. His support and friendship have gone beyond what one can thank someone for.

Barry Richards, who as a supervisor kept punching holes in whatever I presented to him as argument. If there is some coherence in what follows, it is certainly due in no small respect to his continuing willingness to debate the issues.

My friends and colleagues at the Centre, for remarks and comments at workshops or seminars. I hope that submission of the dissertation will finally put a stop to jokes like "Are you feeling tense?" and "Isn't it about time you're giving a talk?".

Mijn ouders, die me bleven steunen doorheen de jaren, ook al hebben ze zich waarschijnlijk vaak afgevraagd waarom het toch zo lang duurde.

And Mimo. (words fail)

Abstract

English exhibits a rich apparatus of tense, aspect, time adverbials and other expressions that can be used to order states of affairs with respect to each other, or to locate them at a point in time with respect to the moment of speech. Ideally one would want a semantics for these expressions to demonstrate that an orderly relationship exists between any one expression and the meanings it conveys. Yet most existing linguistic and formal semantic accounts leave something to be desired in this respect, describing natural language temporal categories as being full of ambiguities and indeterminacies, apparently escaping a uniform semantic description.

It will be argued that this anomaly stems from the assumption that the semantics of these expressions is directly related to the linear conception of time familiar from temporal logic or physics - an assumption which can be seen to underly most of the current work on tense and aspect. According to these theories, the cognitive work involved in the processing of temporal discourse consists of the ordering of events as points or intervals on a time line or a set of time lines.

There are, however, good reasons for wondering whether this time concept really is the one that our linguistic categories are most directly related to; it will be argued that a semantics of temporally referring expressions and a theory of their use in defining the temporal relations of events require a different and more complex structure underlying the meaning representations than is commonly assumed. A semantics will be developed, based on the assumption that categories like tense, aspect, aspectual adverbials and propositions refer to a mental representation of events that is structured on other than purely temporal principles, and to which the notion of a nucleus or consequentially related sequence of preparatory process, goal event and consequent state is central.

It will be argued that the identification of the correct ontology is a logical preliminary to the choice of any particular formal representation scheme, as well as being essential in the design of natural language front-ends for temporal databases. It will be shown how the ontology developed here can be implemented in a database that contains time-related information about events and that is to be queried by means of natural language utterances.

Contents

Abstract	4
1. The procedural study of temporal expressions	7
2. The referential nature of tense	14
2.1 Tense as anaphor	14
2.2 Referential accounts of temporal expressions	21
2.2.1 Reichenbach's reference times	22
2.2.2 Computational approaches	24
2.2.3 Formal approaches	27
2.3 Non-referential approaches	32
2.4 Problems with the referential account	34
2.5 Conclusion	36
3. Temporal ontologies: points, intervals and events	38
3.1 Introduction	38
3.2 Points, intervals, events	39
3.3 Conclusion	49
4. A typology of temporal descriptions	51
4.1 Introduction	51
4.2 Tense, aspect and Aktionsarten	51
4.3 The taxonomy	55
4.4 Conclusion	66
5. An analysis of temporal expressions	67
5.1 The aspectual nature of some temporal expressions	67
5.1.1 For and until	67
5.1.2 In-adverbials	71
5.1.3 Negation	74
5.2 Progressives and the Imperfective Paradox	75
5.2.1 Progressive states	75
5.2.2 A functional account	79
5.2.3 The imperfective paradox	86
5.3 Perfects	94
5.3.1 Some semantic descriptions	94
5.3.2 Consequent states	96
5.3.3 McCawley's and Comrie's 4 types of perfect	101
5.4 The Perfect Progressive	103

5.5 Conclusion	104
6. The temporal structure of discourse	106
6.1 Introduction	106
6.2 Temporal Connection	107
6.2.1 When	107
6.2.2 Other temporal connectives	116
6.2.3 Presuppositions and event descriptions	118
6.3 The temporal structure of discourse	120
6.4 Conclusion	129
7. The aspectual classification of event descriptions	130
7.1 Introduction	130
7.2 Aspectual categories and tenselessness	130
7.3 Diagnostic tests for the categories	134
7.3.1 Stative expressions	136
7.3.2 Event expressions	140
7.4 Aspect and compositionality	145
7.4.1 Mass terms, bare plurals and aspectual class	150
7.5 Conclusion	154
8. Temporal information for natural language processing	156
8.1 Introduction	156
8.2 Extracting temporal information from text	157
8.3 Temporal representation models	163
8.3.1 The situation calculus	163
8.3.2 Ontologies with temporal characteristics	165
8.3.3 Event-based ontologies	171
8.3.4 Conclusion	175
8.4 An implementation of the episodic representation scheme	175
8.4.1 Introduction	175
8.4.2 The database	179
8.4.3 Aspect and aspectual adverbials	184
8.4.4 Anaphoric tense and when-clauses	190
8.4.5 Program and sample session	193
8.5 Conclusion	198
References	201

Chapter 1

The procedural study of temporal expressions

Our ordinary language shows a tiresome bias in its treatment of time. Relations of date are exalted grammatically as relations of position, weight and color are not. This bias is of itself an inelegance, or breach of theoretical simplicity. Moreover, the form that it takes - that of requiring that every verb form show a tense - is peculiarly productive of needless complications, since it demands lip service to time even when time is farthest from our thoughts. (Quine 1960: 170)

It has often been remarked, though not always with the same degree of exaggeration or exasperation as is exhibited in Quine's words, that the expression of temporal relations plays an important role in language, and that - as an obvious correlate - the processing of temporal information constitutes an important part of natural language understanding.

It is therefore not surprising that many attempts have been made to develop logical systems that try to give an account of the function of temporal expressions in language. Ideally, systems like these should be abstractions of the processes people engage in as they produce and process English sentences; that is, a logic of temporal expressions should explain what takes place in the process of relaying and extracting temporal information in natural language discourse, and then abstract from this account simple, general rules that govern the usage of temporal expressions.

In very general terms, the processing of temporal information could be described as consisting of the construction of a serial representation of the events, processes and situations (for all of which I will use the general term "states of affairs") talked about in the discourse. Constructing such a serial representation involves anchoring the states of affairs to our conception of the time dimension, i.e. ordering them along the real time line, or along expected time lines in the future, or along imaginary alternative time lines now. These states of affairs can be ordered with respect to each other, or with respect to some pre-established instance on the temporal dimension - usually, though not necessarily, the moment of speech. The cognitive work involved in understanding natural language temporal expressions consists of creating and updating the particular contents of these serial representations (cf. Miller & Johnson-Laird 1976: 413).

It seems, then, that an important task to be carried out when constructing a temporal semantics

for a natural language is to determine the nature of the underlying time concept that is involved in all this.

As was pointed out by Bach (1981), one should not try to answer this kind of question by asking native speakers what they *think* the underlying time concept looks like. The correct approach seems to be, rather, to work from a grammatical analysis of temporal language towards an account of its conceptual basis.

Yet, for various reasons, this has always turned out to be a formidable task. To begin with, as Miller & Johnson-Laird (1976: 411) point out, temporal information can be conveyed by words in all the major syntactic categories, such as verbs (*begin, end, precipitate, recur*), nouns (*year, season, precedent, minute*), adjectives (*recurrent, successive, present, later*), adverbs (*eventually, often, shortly, subsequently*), prepositions (*at, on, during, in*) and conjunctions (*before, just as, until, as soon as*). An analysis of temporal language would involve a study of virtually all categories of the language, *and only then* would one be able to say something about the conceptual apparatus underlying the natural language temporal system.

Moreover, merely collecting all expressions that convey temporal information and studying their semantic import will not suffice, since many of these expressions interact in complicated patterns, revealing unexpected and often seemingly inexplicable changes in meaning. Thus, it would seem like a straightforward and attainable goal to describe the semantics of a simple present tense; such an account could, for example, describe the present tensed state of affairs as true at the moment of speech or as currently holding, as in (1a):

- (1) (a) John loves Mary

Yet, the meaning of this simple tense morpheme seems to change rather drastically in combination with a verb of a different type (as in 1b), and yet again in combination with an adverbial as in (c) (cf. Miller & Johnson-Laird 1976: 412):

- (1) (b) John kisses Mary
(c) John kisses Mary today

The expression in (b) describes an habitual state of affairs, or a running commentary on a specific state of affairs. As a commentary, it may be reporting a past state of affairs using the historic present, a currently ongoing one, or one that is yet to happen. The expression in (c) unambiguously describes a state of affairs that has yet to happen.

Since the ambiguity exhibited in example (1) seems to be related to the type of the main verb,

the next step in the research could be to define the temporal nature of verbs and classify them according to their temporal profile. A verb like *love*, for example, could be classified as stative, giving rise to a different semantic interpretation when used in the simple present than an event verb like *kiss*. And whereas *kiss* describes an event that can take some time, an event verb like *discover* could be described as being punctual or non-extended, as illustrated in (2a). But these temporal profiles can change under the influence of other expressions, as is illustrated in (2b) and (c) where *discover* has an iterative meaning (cf. L. Carlson 1981):

- (2) (a) I discovered an old hidden staircase in my cellar.
- (b) I discovered many a nice beach in Corfu last summer.
- (c) Many people discovered the white sandy beach near
 the olive yard this year.

Hurtig (1974) notes an even stranger and apparently more intractable related phenomenon, illustrated in (3):

- (3) (a) For more than 12 years, Mary shared all her worries and
 joys with the dead man.
- (b) For more than 12 years, Mary shared all her worries and
 joys with a dead man.

The wide range of grammatical categories with which temporal information can be expressed, the complicated patterns of interaction between them, and the fact that one and the same expression can convey a diverse set of seemingly unrelated temporal meanings has made it difficult to discern any systematic principles underlying the grammar of temporal language. The strategy of analyzing language to discover the underlying conceptual basis and then use these concepts to build a temporal logic for natural language expressions seems doomed to failure.

Because of these apparently insurmountable problems, researchers began building their formal accounts from the opposite direction, taking as their starting point conceptual frameworks borrowed from the logical study of time, and applying these to the study of language.

At first blush, this strategy also seems to have a lot to commend it. After all, temporal logicians have studied extensively the nature of time and can provide us with a conceptual apparatus the properties of which are well understood. All that is needed, so it seems, is an account of how natural language expressions map states of affairs onto this conceptual structure.

And yet, this strategy is very misleading in a number of ways. One of its misconceptions, the most deep-rooted one, has to do with the very structure of time. Most temporal logicians will

agree that time consists of past, present and future, and that the future is just like the past - apart from the fact that it *follows* the present rather than preceding it. However, linguists and semanticists concerned with a proper descriptive account of natural language data noted early on that the basic temporal distinction in a language like English is *twofold*, not *threefold*:

English grammar has no device whatever for cutting future time away from the time of speaking. (Joos 1964: 135)

On the basis of the tenses, it is possible only to distinguish the past from the non-past. Thus, (4a) is clearly past, combining most naturally with an adverbial like *yesterday*; (4b) is clearly non-past, not allowing combination with an adverbial referring to a past time:

- (4) (a) John played squash
 (b) John plays squash

As was discussed before, a present tense as used in (4b) probably describes an habitual or future state of affairs, combining most naturally with an adverb like *often* or *tomorrow*. In other words, the present tense only indicates non-pastness and does not on its own allow a further disambiguation between present or future time. To communicate in English that something is really present or going on "at the present time", the progressive can be used:

- (4) (c) John is playing squash

But to say that the expression in (c) denotes the logicians' present time is complicating matters rather than resolving them: the present progressive in (c), again, only describes a non-past state of affairs; the actual location of the state of affairs described in (4c) could be both in the present, or be planned for the future.

The other conceptual notion often found in temporal logics, viz. that the future is logically speaking the exact mirror image of the past, is also not reflected in language. As Lyons remarks (1977:677), futurity in language is never a purely temporal concept; it necessarily includes an element of prediction or some related modal notion. There is no *a priori* reason why languages could not treat future time predictions as grammatically parallel with statements about the past, but in general they don't.

It should be clear from this brief discussion that taking a pre-established conceptual framework to study the grammar of temporal relations can very easily lead to unnecessary complications in the grammar, or will leave things unexplained that need explaining.

Linguists and formal semanticists who still want to pursue this line of research will then be forced to adapt the logical framework they started off from. This, in a sense, defeats the purpose of their enterprise: one of the reasons for starting off from the theories and concepts

offered by temporal logic is that the properties of these logics have been examined extensively and are very well understood. Having to adapt them to fit the data under description means that one is likely to end up with theories very different from the ones one started off from, and the properties of which are as ill-understood as those of any other novel theory.

We seem to have reached an impasse here. On the one hand, I have tried to show that a study of temporal expressions in language which takes as its starting-point a particular conceptual analysis of time can easily lead to inaccuracies in the descriptive apparatus. This is clearly an undesirable result, and it seems like a better idea to return to the first option, i.e. that of starting from a grammatical analysis of temporal language and working towards an account of its conceptual basis. But, as I also tried to indicate briefly, this approach turns out to involve an almost impossible task, leading more often than not to theories full of unexplained gaps and apparent ambiguities, leaving no room for significant generalization.

Ideas recently advanced in computational linguistics may suggest a way out of this dilemma. There is a general intuition shared by speakers of natural language that the comprehension of language proceeds incrementally, and that at every point in the processing of a sentence not only the *sense* of expressions is available to the understander, but also their *referents*, i.e. the entities referred to in the domain of discourse. This view of natural language comprehension in which rules of syntactic and semantic processing are closely linked has led to the development of novel theories of syntax, giving natural language sentences the kind of left-branching structures needed to account for the way the processor computes interpretations incrementally (cf. Steedman 1986).

But, since the interpretation of many natural language categories is intimately bound up with the manner in which the left-to-right incremental evaluation progressively changes the context in which its components are evaluated, the idea of incremental evaluation also has consequences for natural language semantics itself. For one thing, it makes it hard to draw a clear boundary between semantic aspects of meaning, and pragmatics. And what becomes even harder to do is to actually specify the semantics of certain linguistic categories without thinking of their meaning in terms of a theory in which the concept of a procedure or process and the related concept of a changing context of evaluation are not explicitly represented among the primitives.

In this thesis, I will defend the claim that tense and related temporal categories constitute a

phenomenon that should be looked upon in this way, i.e. they are expressions the semantics of which depends crucially on the changing context of the conversation or the discourse in which they occur. As was pointed out before, the cognitive work involved in the processing of temporal expressions consists of the construction and updating of some serial or otherwise time-related representation of the states of affairs talked about in a discourse. This representation constitutes the continually changing context in which incoming temporal expressions have to find a place.

I will claim that many of the ambiguities that always seem to plague the grammar of temporal expressions are ambiguities arising from this process of reference rather than being ambiguities of sense. Given an appropriate account of the mechanism of reference, apparently diverse meanings of particular temporal expressions can be seen to be derived from a single sense.

If we do take seriously this referential view of tense, procedural semantics can offer us a way out of the deadlock noted before with respect to the strategy one should adopt when studying temporal expressions. Indeed, it can certainly be argued that the most successful theories of reference are expressed as or exemplified by computer programs. The reason for this is simply that the idea of a changing context with respect to which expressions are evaluated resembles closely that of the changing state of the variables which a computer program accesses during computation (cf. Isard 1975). Programs therefore offer a helpful notation for those pragmatic aspects of reference that are most intractable in non-procedural terms - and with which I will argue the meaning of temporal expressions is intimately bound up. In fact, Isard himself developed a program that used this technique to process temporally referring expressions (Isard 1974). This program, which formed the starting point for many of the later procedural approaches to matters temporal, will be discussed in the following chapter.

Since the referential nature of tense is crucial to the approach to be developed here, it is to this idea that I will turn first. I will briefly explore a theoretical construct, due to Reichenbach (1947), which underlies many of the procedural and formal accounts of temporal reference. I will show how this idea, if implemented in a naive way, leads again to the apparent ambiguities which plague most accounts of temporal expressions and which we had in fact set out to avoid. Throughout this discussion, I will concentrate on those problematic natural language constructions that will be treated extensively later on. In chapter 2, I will also give the essentials of the solution to be developed in subsequent chapters.

In chapter 3, the conceptual nature of this solution will be compared with the concepts underlying some of the current approaches to tense and aspect. No attempt will be made to exhaustively survey all the existing formalisms but rather to sketch their most salient conceptual features. This will allow for detailed comparisons in chapters 4 and 5 between the way these formalisms account for certain puzzling constructions and the solution developed here. In chapter 6, the results of this account will be used to sketch a general theory of the temporal structure of discourse. In the light of all these findings, some of the basic tenets of this kind of approach to tense and aspect will have to be reconsidered; this will be done in chapter 7.

Although the starting point of this study is a procedural one, most of the work carried out here is conceptual rather than procedural in nature. In chapter 8 I will, however, point to the practical feasibility of this approach in the study of natural language understanding, and compare it with some existing Artificial Intelligence applications, notably in the construction of natural language front-ends to systems that are intended to store temporal information as conveyed by means of natural language text.

Chapter 2

The referential nature of tense

2.1. Tense as anaphor

There is a long tradition of tense analysis based on insights due to Prior (1967). Before Prior, in standard propositional logic, a sentence like *Harry works in the garden* was analysed as involving no reference to a specific time, and was simply represented by a propositional variable, say p . Prior changed the nature of propositions fundamentally. In his account, a propositional variable like p stands for "It is the case *at this moment* that Harry works (is working) in the garden". In order to be able to refer to other times than the present, Prior introduced operators like P and F , which are interpreted as *at least once before now it was the case that* and *at least once after now it will be the case that*. These operators can combine with sentences to form new well-formed sentences. The truth-conditions for these operators were formulated as involving existential quantification over times. They can be paraphrased as follows:

- (5) Pp is true at a time t
iff there is a time t'
such that t' is before t
and p is true at t'

Thus, a sentence in the simple past (like 6a) is said to be true if *there is some time in the past* at which its present tense counterpart (6b) is true (cf. Montague 1973; Dowty 1979).

- (6) (a) Harry worked in the garden.
(b) Harry works in the garden.

It has often been remarked, however, that a past tense is more definite than Priorean tense logic operators suggest. Consider (7):

- (7) I didn't turn off the stove.

When uttered, for instance, by a man on his way to the airport, (7) does not mean that at some time or other in the past he didn't turn off the stove. The sentence clearly refers to a particular time, the identity of which should be clear from the context (cf. Partee 1973). The definite nature of this type of temporal reference can also be observed in discourse, as is illustrated in (8). If someone asks me

- (8) (a) What did you do after class this morning?

and I reply

- (8) (b) I ate lunch

then I mean that I ate lunch at the particular past time we were talking about.

This definite use of the simple past is traditionally contrasted with the indefinite or quantificational use typically exhibited by a present perfect expression e.g. Leech 1971). When uttering (9a), it is claimed, one is referring to some indefinite state of affairs in the past; this is very different from the definite reading associated with a simple past as in (b):

- (9) (a) Have you been to America?
(b) Did you go to America?

The indefinite nature of the perfect is also evident in discourse. Replying to the question in (8a) with (8c) would be rather evasive or even sound irrelevant:

- (8) (a) What did you do after class this morning?
(c) I have eaten lunch.

Most often, the indefinite interpretation of the present perfect is reinforced by means of adverbs like *ever*, *never* or *before*. If this kind of reinforcement is absent, the perfect auxiliary tends to be stressed to get the indefinite reading:

- (10) - Have you ever eaten caviar before?
- No. But I *have* eaten oysters.

As Leech (1971: 32) points out, "indefiniteness" of the perfect as illustrated in (10) stands for two different things at once. First, the *number* of states of affairs referred to by the perfect is unspecified and may be more than one. Secondly, the *time* of the state of affairs is also left unspecified. It follows that Prior's characterization of the past time operator *P* as *at least once before now it was the case that* is in fact a very suitable rendering for the semantic import of the present perfect, rather than of the English simple past. In chapter 5, an account will be offered of the perfect which is quite different from the "indefinite" one offered by Leech.

The idea that a past tense morpheme refers to a particular time in the past obviously does not mean that it is always possible to accurately *identify* or *describe* that time. Just as one can use an expression like *yesterday* felicitously without knowing the date, one can utter (11) without being able to provide the exact time of the event talked about (cf. Barwise & Perry 1983: 35):

- (11) Caesar crossed the Rubicon
Philadelphia was founded by William Penn

What makes these sentences special is the uniqueness of their topic: Philadelphia, for example, is a very definite place, and was founded at a very definite time in the past. A simple past is used here exactly because of the fact that it refers in a definite way (Leech 1971: 37) - not in

the sense that it *picks out* a particular time, but by indicating that the event took place at a particular time. To use a perfect in these cases would certainly constitute odd usage.

Examples like these are, nevertheless, sometimes said to involve *indefinite* reference (cf. Kuhn 1979) exactly because the time of the state of affairs is left unspecified. However, this would be tantamount to saying that the noun phrase *the driver* in (12) refers in an indefinite way because the identity of the driver is left unspecified:

- (12) A car came round the corner. The driver was obviously drunk.

Also, the simple past in (11) does not have the interpretation of *at least once* which is part of the indefinite nature of the present perfect (cf. 10) and of the Priorean definition of the past tense operator.

A number of caveats have to be made about this view of the simple past as resembling some form of definite reference. First, it is sometimes pointed out that there are instances where a simple past tense does seem to require a representation in terms of quantification over times. This is obviously the case with sentences that contain an existential quantifier, as in (13):

- (13) John sometimes got extremely obnoxious.

It can be claimed, however, that the past tense in (13) still picks out a particular contextually defined past interval, relative to which *sometimes* acts as an existential quantifier. This is illustrated in (13'), where the past tense *got* singles out the interval referred to in the previous sentence for *sometimes* to quantify over.

- (13') Last year, we traveled across Europe with John.
He sometimes got extremely obnoxious.

It should be noted that the interval which *got* singles out does not coincide with the one indicated by means of the adverbial expression *last year* but is the one associated with the *event* of *traveling across Europe*.

Matters get slightly more complicated with sentences containing a universal quantifier, as in (14):

- (14) (a) I always said Harry would end up in prison.
(b) I never read such a load of rubbish.

Leech considers these constructions to be "idiomatic exceptions" to the rule that the simple past refers in a definite way (Leech 1971: 38). They can usually be replaced by their present perfect counterpart:

- (14') (a) I've always said he would end up in prison.
 (b) I have never read such a load of rubbish.

Clearly, the simple past can still single out a very specific past interval for the universal quantifier to range over, as is illustrated in (15):

- (15) When Harry came for his summer holidays,
 he always built a sandcastle on Grovely beach.

In fact, without the additional *when*-clause to limit the set of times that *always* quantifies over, the sentence sounds distinctly odd:

- (15') John always built a sandcastle on Grovely beach.

These examples illustrate that it would be misleading to say that a past tense morpheme always refers in a definite way. It is, rather, by using a *sentence* containing a simple past that a speaker *can* refer to a definite time in the past, provided this sentence describes an *event*. If the sentence describes an habitual state in the past or a universally quantified over event then, because of the nature of habitual or universal statements, no particular past time period needs to be identified - as is illustrated in (14). If, however, the nature of the state of affairs talked about does not make a universal reading easily accessible, the sentence will sound odd without an explicit indication of the intended past period, as is illustrated in (15'). A major topic of subsequent chapters will be to define the nature of these events and to distinguish between sentences that describe events and those that do not.

There also seem to be uses of the simple past involving propositional attitudes for which a quantificational interpretation *is* appropriate (Cooper 1985). Consider (16):

- (16) John thinks that she wrote a book about syntax.

The past tense morpheme in (16) could certainly have a definite reading, e.g. when it is used to answer the question in (16a):

- (16) (a) What does John think that Mary did last summer?

The past tense then refers to a particular time in the past, viz. *last summer*. But, Cooper argues, the past in (16) can also have a quantificational reading, which can be paraphrased as in (16b):

- (16) (b) John thinks that there is some time in the past
 at which she wrote a book.

If (b) really constitutes a possible reading for (16), then it remains to be explained why this function of tenses can change in certain embedded contexts - something I will not touch upon in the remainder of this work. Cooper's data does seem to require a relaxation of the statement about the definite nature of the simple past, saying that a simple past *may* refer in a definite way, but need not. This way one could also account for the by now well-documented

fact that (certain uses of) the present perfect are being replaced in American English by the simple past (cf. Quirk et al. 1985: 19): for American English this trend seems to require both a definite as well as an indefinite (quantificational) account of simple past constructions.

An account of the past that accommodates both its definite and the indefinite uses has been proposed by Kuhn (1979). He suggests that the past be treated as a quantifier over a set of possible reference times, where the context will serve to limit this set. In terms of the processing model sketched in the previous chapter, this means that the occurrence of a simple past is a signal to the hearer that the context has to be searched for a suitable temporal reference entity with respect to which the current past tense is to be interpreted. As Ritchie (1979: 90) remarks, "context" is to be taken here to mean the entire knowledge of the hearer of the sentence, where the sentence itself becomes part of its own context of utterance. Thus, a sentence like

(17) Angus went to school in Edinburgh

does not sound odd if the speaker knows that Angus is educated, and hence probably went to school at some time (Ritchie 1979: 90). Or, if I notice you are wearing new shoes, I can infer that you bought them at some (recent) point in the past, and then go on to refer to this implicitly defined past time to acquire further information about your recent purchase, using a simple past as in (18):

(18) Where did you buy those shoes?

In fact, the interval in the past to which the simple past tense morpheme refers can itself be identified in a very indefinite way. Consider:

(19) Some time last summer, John left for California.

The adverbial expression, indefinite though it may be, picks out a past time for the tensed clause to refer back to.

Keeping in mind what was said in chapter 1 about the way we process temporal information in language, the idea that a simple past refers in a definite way can now be refined somewhat. When processing temporal information in discourse, the hearer is involved in building a structured representation of the state of affairs talked about in the discourse. At every stage in this process, the structure built up so far serves as a context against which new expressions are evaluated and with respect to which new states of affairs have to be situated. A simple past sentence describing an event in the ongoing discourse has the capacity of picking up a previously introduced event with respect to which it is to be situated in the representation under discussion.

It was remarked quite early on in the literature on temporal reference that the distinction between the definite nature of the simple past and the indefinite nature of the present perfect parallels the contrast in meaning between the definite and the indefinite article (cf. Leech 1971: 36-38). An expression like *the man* is used rather than *a man* if a particular man has already been introduced in the discourse, or else if it is known from the context which person is being talked about. Similarly a simple past is used to refer to a time already introduced in the discourse (as was illustrated in 8b), or to a particular time that is clear from context (as in 7). And just as it is normal to start a conversation indefinitely and then continue by means of definite reference (as in 20), a past can be used to follow a perfect (as in 21):

- (20) *A man and a woman* entered the room. *The man* said
he wanted to talk to me about life.
(21) A: I've only *been* to Australia once.
B: *Did* you like it?
A: It *was* marvelous.

The parallels illustrated in these examples between temporally and nominally referring expressions seem to reflect a deeper phenomenon, however: just as the definite description *the man* and the pronoun *he* are used anaphorically in (20), referring to the previously introduced male entity, so the past tense in (21) can be described as referring to the previously introduced temporal entity. And just as (22a) is odd when uttered in a context without prior mention of a person for the *he* to refer to (as in 22b), (23a) is odd unless the context provides an antecedent for the past tense to refer to, as in (23b) (cf. Allen 1966, McCawley 1971, Partee 1973).

- (22) (a) ?He likes you very much.
(b) I met your brother last night. He likes you very much.
(23) (a) ?We had a great time.
(b) We went to a party last Friday. We had a great time.

Partee (1973) suggested that the parallels between nominal and temporal anaphora could be accounted for by invoking explicit variables over times. The past, for example, can be translated as a free variable with values restricted to past times. In some cases, tenses are bound by temporal quantifiers in the form of other tense morphemes (24a), certain time adverbials (b) or temporal conjunctions (24c; cf. Hinrichs 1986: 63-64); sometimes they remain free and are interpreted contextually, just as free pronouns are (cf. 25):

- (24) (a) He went into the bathroom and took a shower. Two hours
later, he was found dead in his bed.
(b) Sue had a party last Friday. We all got terribly drunk.
(c) When we arrived at the party, John was just leaving.

- (25) I left the gas on.
I didn't turn off the stove.
Did you put the cat out?

Dowty (1982: 44) argues, however, that the parallels between temporal and nominal anaphora are not as clear-cut as that. When a pronoun occurs in a sentence with a possible antecedent (as in 26), it is still ambiguous between a bound and a free reading.

- (26) Every man in this department thinks he is smart.

The anaphoric properties of tense are rather different, Dowty claims. In a sentence with a time adverbial, like (27), there is no free reading for the tense anaphor:

- (27) Yesterday, John left.

This puzzle can best be looked at in terms of how expressions are evaluated against a changing context (cf. chapter 1), and - more importantly - by looking at the constructions that set up the context with respect to which a subsequent expression will be evaluated. There are, in English, few - if any - devices whose only function is to bring into focus an item so that it can be referred to subsequently by means of a pronoun. A possible candidate for such a device could be a dislocated topic as in (28):

- (28) As for Henry, he's really smart.

But even here, the use of the focussing construction need not necessarily be in the service of a pronoun, as can be seen in (28'):

- (28') As for Henry, now there's a man you can rely on.

There are, however, devices whose only function seems to be to provide referents for tenses, *when*-clauses constituting the most obvious example. A situation described in a *when*-clause always serves as the referent of the tense in the main clause (and sometimes even as a referent for the tense morphemes in subsequent clauses). The difference between (27) and (26) does not seem to lie, then, in the nature of the anaphoric expression, but rather in the nature of the expression that brings into focus the element for the anaphor to refer to: temporal adverbials do not appear to behave like the quantifier in (26). It follows that tenses can still be said to be anaphoric in nature, and that Dowty's point only illustrates that the expressions that establish the entities for tenses to refer to are more like left-dislocated topics than like quantifiers or other expressions that can be used to bring into focus objects for pronouns to refer to (cf. Isard 1974: 246; Steedman 1981).

An important difference remains, however, between the use of tenses in discourse and that of

personal pronouns. Consider (29):

- (29) Oliver came in, walked over to the window, opened it and jumped.

In this text, there is a natural inclination to assume a forward movement of time and to interpret the events as having occurred in the order in which they are described. This seems to indicate that the second event refers to a time "just after" the time associated with the first event, and that this event makes available a time "just after" it for the third event description to refer back to. It follows that tenses seem to have the ability to refer to a temporal entity that was *implied* rather than explicitly mentioned in the previous event description. Moreover, whereas personal pronouns refer back to a previously introduced entity without adding a new referential entity to the model of the discourse, tenses refer to a previously introduced temporal entity and then create a new temporal entity that can be used for subsequent reference. This means that the anaphoric nature of tense is more akin to that of definite descriptions as in (30) than that of pronouns (cf. Webber 1987):

- (30) We unloaded the picnic. *The beer* was warm.

In what follows I will, keeping these caveats in mind, defend the idea that a past tense is an anaphoric element in that it does *not* mean "some time in the past", but refers to a (more or less) definite time in the past, specified by a linguistic antecedent or by non-linguistic context. Even if one wants to argue that there are truly "indefinite" uses of the simple past, it still cannot be denied that a simple past *can* refer to a well-defined entity. A further specification of the exact nature of such a temporal referent will constitute the major theme of this and following chapters.

2.2. Referential accounts of temporal expressions

A number of proposals have followed the implication that the meaning of tenses should be represented in the same way as that of anaphoric expressions in the nominal domain. Hinrichs (1986), Kamp & Rohrer (1983) and Partee (1984) have exploited the idea within a framework of logic-based semantics. Isard & Longuet-Higgins (1971), Isard (1974), Ritchie (1979) and Steedman (1981, 1982) have done so within a computational framework. In all these accounts, some version of Reichenbach's notion of reference time plays a crucial role. It is to this notion that we turn next.

2.2.1. Reichenbach's reference times

Reichenbach (1947) was one of the first to suggest that a past tense should not be treated as quantifying over times past, but as referring to a specific time in the past. He analyzed semantic distinctions in the area of temporal reference in terms of three temporal entities. Of these, the speech time *S* and the event time *E* are self-explanatory. A third time, the reference time *R* is somewhat harder to define. It corresponds to the notion of the time that is being talked about, or

the temporal standpoint from which the speaker invites his audience to consider the occurrence of the event (Taylor 1977: 203).

Reference time should be thought of as a theoretical entity designed to explain vague notions like "more past than normal past" or "before past" which were used in traditional grammars (like Jespersen 1924) to account, amongst other things, for the difference between a simple past and a past perfect.

The advance Reichenbach made over previous treatises like Jespersen's was that reference times were said to play a role in *all* the English tenses. Reichenbach's three times can be ordered with respect to each other, different orderings resulting in different English tenses. In the case of the simple past, the reference time is coincident with the past event time. That is, in a sentence like *John left* the event of leaving is situated somewhere in the past and coincides with a past reference time the exact location of which must be determined by context. In *John had left* the event time is also past, and the reference time is situated somewhere between that event time and the time of speech - the exact location again to be determined by context or cotext. In a present perfect, the reference time is also divorced from the past event time but coincides with the present. Relations like these can be represented pictorially as follows:

- (31)
- | | | |
|---------------|-------------------|---|
| | E,R | S |
| (a) John left | -----+-----+----- | |
-
- | | | |
|-------------------|-------------------|-----|
| | E | R,S |
| (b) John has left | -----+-----+----- | |
-
- | | | | |
|-------------------|-------------------------|---|---|
| | E | R | S |
| (c) John had left | -----+-----+-----+----- | | |

Reichenbachian reference times have found their way into numerous theories of tense (e.g. Dinsmore 1982; Hornstein 1977; Nerbonne 1984; Yip 1985). They are assumed to be of central importance when accounting for a number of tense-related problems. I will here briefly

discuss three of these problems that will re-appear in later chapters.

The first area where reference times are said to play a fundamental role is in the interpretation of time adverbials. In traditional tense logics, there has always been a problem with the treatment of tenses in relation to certain adverbials. In a sentence like (32)

(32) Harry left yesterday

the past tense indicates that Harry's leaving occurred in the past (in a Priorean framework: at some indefinite past time); the adverb *yesterday* also situates Harry's leaving in the past, more precisely on the day before today. Assuming two Priorean tense operators corresponding to these two temporal entities (*P* for past and *Y* for yesterday), we can render (32) in two ways:

(32') (a) *P* [*Y* (Harry leave)]
(b) *Y* [*P* (Harry leave)]

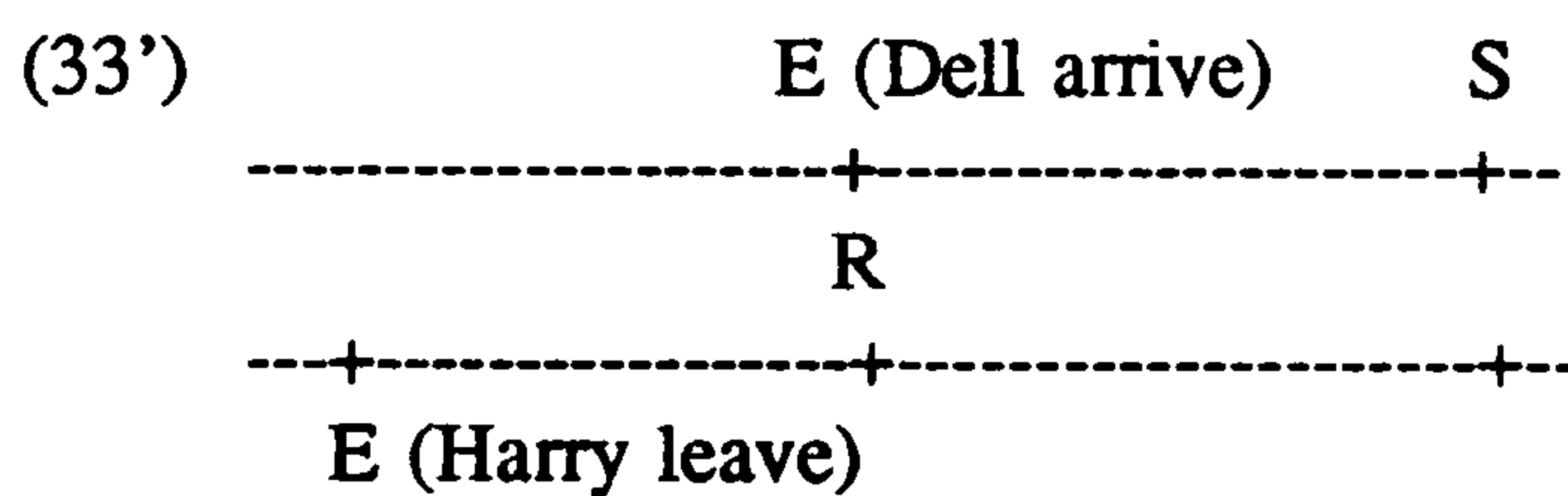
But both representations turn out to be wrong. According to (a), (32) is true if there is some time in the past, possibly last week, at which *Harry leave yesterday* is true. And according to (b), (32) means that yesterday there was some time in the past, e.g. last Sunday, at which *Harry leave* is true. In both cases, Harry's leaving is allowed to be earlier than yesterday (cf. Dowty 1982).

Reichenbach's notion of reference time offers a solution to this problem (cf. Bauerle 1979). The trick is to take temporal adverbials as describing the reference time: in (32), the adverbial *yesterday* determines where the reference time is located. Since for a simple past sentence the reference time coincides with the event time, the event of *Harry's leaving* is then correctly described as taking place *yesterday*. This way Reichenbach's reference time also captures the anaphoric nature of tense: the past tense does not refer to some indefinite time in the past, but to some (contextually or cotextually) pre-established reference time.

A second problem for which reference times provide a solution is the interpretation of complex sentences with temporal conjunctions, as in (33):

(33) When Dell arrived, Harry had left.

For constructions like these, Reichenbach proposed a principle called "permanence of the reference point" (Reichenbach 1947: 293): the reference times of both subordinate and main clause have to coincide. For (33), this can be represented schematically as follows:



Since the *when*-clause contains a simple past, the event time (i.e. the time of Dell's arrival) coincides with the reference time. The perfect of the main clause locates the event of Harry's leaving somewhere before the reference time. Permanence of the reference point results in the correct interpretation that Harry's leaving occurred before Dell's arrival. Again, Reichenbach's reference time provides a way of talking about the anaphoric nature of tense. As was mentioned in the previous section, *when*-clauses are used typically to provide a temporal referent for the tense morpheme in the main clause to refer to. In Reichenbach's terms, this means that the *when*-clause provides a reference time to which the speaker refers in the main clause, as is illustrated in (33').

Finally, reference times are also assumed to be of great importance in accounting for the way sentences are temporally related in a discourse. Consider (34).

(34) Dell arrived late. Harry had already left.

It is easy to see how the temporal relation between the events in this discourse can be accounted for in ways similar to the one that was just sketched for temporal conjunctions. Again, the anaphoric nature of tense finds a straightforward translation in Reichenbach's framework.

2.2.2. Computational approaches

Early Artificial Intelligence work on the processing of temporal expressions incorporated a notion of temporal reference very similar to Reichenbach's. Isard (1974) describes a computer program that can answer questions about hypothetical and actual situations in past and future concerning a game of tic-tac-toe. One of the main ideas behind the program is

a 'pronominal' account of both tense and mood as forms of definite reference to previously mentioned situations (Isard 1974: 233).

The program was capable of playing a game of tic-tac-toe, after which it could engage in a short dialogue about the game:

- (35) Had you taken eight when I took five?
 - NO
 If I had taken six when I took five, would you have taken
 what you did?
 - NO
 What would you have taken?
 - 4

Isard's program uses a referent setting device consisting of two slots, called PRESENT and REMOTE, into which reference times are put; this principle reflects the twofold nature of the English tense system mentioned in the previous chapter. A simple past sentence (but also a subjunctive) locates the reference time of that sentence in the REMOTE slot. The following sentence with a past (or remote) tense will automatically refer to the time that currently fills the REMOTE slot. Thus, in *Harry had left when Frank arrived* the simple past *when*-clause puts the event time of Frank's arrival in the REMOTE slot. The main clause also has a REMOTE tense and this picks up as its reference time whatever has been loaded in the REMOTE slot, which is in this case the time of Frank's arrival.

It is worth analysing this process in some more detail. Consider (36):

- (36) Did you take six when I took five?

The program first notes the tense of the *when*-clause in order to know where to look for a situation of the sort described. In (36), the tense is past, so the search goes on in the memory of the past game. If the search fails, a message is printed out saying that the presupposition which should be supported by the *when*-clause does not hold. In the case of (36), it could print something like (36'):

- (36') You haven't taken five.

If the search succeeds, however, the program notes the values of the variables which define the situation it finds, i.e. it notes what noughts and crosses had been taken by user and program at that stage of the game. It then creates a function which, when called, will conjure up this state of the game by assigning these values to the variables. The newly created function is given the label PAST.

During the processing of (36), the past tense main clause is analysed as REMOTE, and this triggers a search for the function currently labelled PAST. The function is run, in the case of (36) recreating the situation of the game at the point at which *I took five* and the program has to answer, with respect to this situation, a question which can be paraphrased as

- (37) Was my next step to take six, or am I in the process of doing so?

A similar strategy is used if the discourse under consideration continues as follows:

- (36") Did you take six when I took five?
 - NO
 Did you take seven?

When processing the follow-up questions *did you take seven?* the REMOTE label in the analysis of this phrase still finds the same function labelled PAST, and hence interprets the follow-up question with respect to the same state of the game as it did the previous question. Values are kept in the referential slots between utterances until they are obliterated by the arrival of a new *when*-clause or conditional, or when there is a tense change.

The vagueness in the program's question (37) allows for certain events to happen at the same time as the extended event as well as for events to immediately follow another event. A special function, called INTRAIN, allows the apparently punctual moves to be thought of as extended or ongoing. Using this mechanism, Isard can account for two "meanings" of *when*, i.e. the simultaneous one (38a) and the consecutive one (38b):

- (38) (a) Did I win when I took five?
 (b) Did you take six when I took five?

Since, in a well-formed game, two moves cannot be made simultaneously, nor can one player make two consecutive moves, the program checks whether *when*-clause and main clause involve the same agent. If they do, as in (38a), the main clause event is supposed to have happened at the same time as the *when*-clause. In this case, the program tries to answer the second part of a question like (37), invoking the INTRAIN function. When the agents are different, as in (38b), the events are necessarily consecutive and the program will concentrate on the first part of (37).

Ritchie (1979) considerably extended this computational treatment of temporal expressions. An impressive range of temporal constructions is handled in his system, including *after*, *before*, *when*, *as soon as*, *while*, *until* as well as *when*. An important advance of Ritchie's system lies in the fact that he allows greater generality in his treatment of these constructions. As was just discussed, in Isard's framework *when* operates on the meaning of a clause to produce a reference time - namely the time of the event referred to by the clause. The *when*-connector then describes a certain relation between the *when*-clause and the main clause (explained in terms of the question in (37) the system tries to answer). For other connectors (like *before* or *after*) the

system will try to answer different kinds of questions. Ritchie proposed that, rather than postulate that the connectors operate on two clauses, it might be better to have them construct different types of reference times from the subordinate clauses. Once such a reference time has been inserted in the appropriate slot, a single procedure for interpreting the main clause can act on these different structures - obviously with different results.

Ritchie also made a major advance in the computational study of temporal expressions by catering for a far wider range of event-types instead of the limited, temporally punctual moves that constitute the events in a board-game. This idea was also pursued in the computational approach of Steedman (1977, 1981), following suggestions made mainly in the linguistics literature. Since the idea of using more as well as more complex event-types forms the starting-point for most of the work to be presented here, I will refrain from further discussion of this issue until chapter 4.

2.2.3. Formal approaches

One of the most important attempts to interpret Reichenbach's proposals in a formal semantics framework was carried out recently by Partee (1984), following work done by Kamp (1981a, 1981b), Hinrichs (1986, written in 1982) and Kamp & Rohrer (1983).

Kamp (1981a) argued that certain phenomena in discourse can only be properly analyzed within a model-theoretic semantics by using a model of the discourse as separate from a model of the world. After a syntactic analysis of language input, discourse representation rules go to work on the syntactic trees and build a discourse model. A text, represented in such a discourse model, is true if the entities in the discourse model can be mapped onto the model of the real world in such a way that their respective properties and the relations between them are preserved.

This theory seems to provide an elegant account of temporal reference. Kamp (1981b, & Rohrer 1983) claims that the significance of tense lies primarily in the temporal relation it establishes *between* the sentence in which it occurs and the sentences which precede it. It signals to the recipient of the sentence how the information in that sentence should be incorporated in the representation already formed of the preceding sections of the text or discourse of which the sentence is a part. This means, in fact, that Kamp's theory tries to capture directly the "cognitive work" that seems to be involved in the processing of temporal expressions (cf. chapter 1).

More "traditional" truth-conditional semantics had little to say about a truth-value of a discourse consisting of several sentences, over and above a statement about the truth-value of each of the sentences separately. Consider (39):

- (39) John entered the room, walked over to the window
and opened it. He aimed his gun and pulled the trigger.

On a naive, Priorean view, (39) would be true if there is some time in the past, e.g. last Friday, at which John entered the room, and there is some time in the past, e.g. this morning, at which John walked over to the window, and there is some time in the past, e.g. Christmas day 1942, at which John opened the window. But that obviously does not suffice as an account of the temporal relations in a discourse. The short text in (39) clearly conveys a definite temporal order between the events described in consecutive sentences. These intersentential relations should be incorporated in whatever it is that determines the truth-conditions of the discourse as a whole.

In Kamp's discourse representation theory, this can be done in a relatively simple way. Discourse representation rules can be formulated, stipulating that a sentence in the simple past introduces a new event which follows the last event introduced, creating the impression that "time moves forward" in a narrative text like (39). A sentence in the progressive introduces an event which overlaps with the last introduced event. This will result in different structures for the following discourses:

- (40) (a) When Harry arrived, Mary phoned the police.
(b) When Harry arrived, Mary was phoning the police.

When looked at in isolation, it is hard to specify what exactly the differences in truth-conditions are between *Mary phoned the police* and *Mary was phoning the police*. Yet, in connection with other sentences, the differences emerge very clearly, as is illustrated in (40). This difference is captured with Kamp's discourse representation rules, which will result in structures containing consecutive events for (a) and overlapping events for (b).

In the account so far, reference times play no role: when an event description is being processed, the location of that event is only stipulated with respect to the last processed event. This is in line with the proposal made by Partee (1973). In that paper - where Partee first introduced the notion of temporal anaphora - it was suggested that the semantic dependency of tense morphemes on temporal adverbs or temporal conjunctions could be accounted for by invoking explicit variables over times.

In later papers, however, the idea of having a direct anaphoric connection to event times was

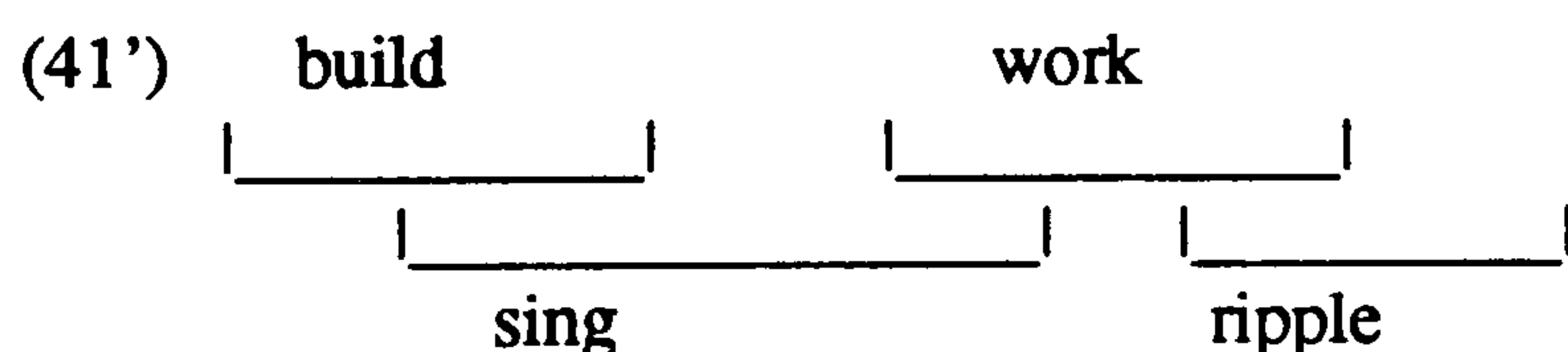
abandoned in favour of a theory in which reference times play a crucial intermediate role (Par-
tee 1984, Hinrichs 1986).

For the treatment of simple past tense event sentences the account remains largely the same as it was in Kamp's approach. Because of the anaphoric nature of tense, an event described in a simple past sentence is interpreted as occurring at a pre-established reference time. A new reference time is introduced just after the newly introduced event, and the next past tense morpheme is interpreted relative to that reference time. The updating of reference times and the stipulation that simple past events are temporally located within the current reference time capture the forward movement of narrative time.

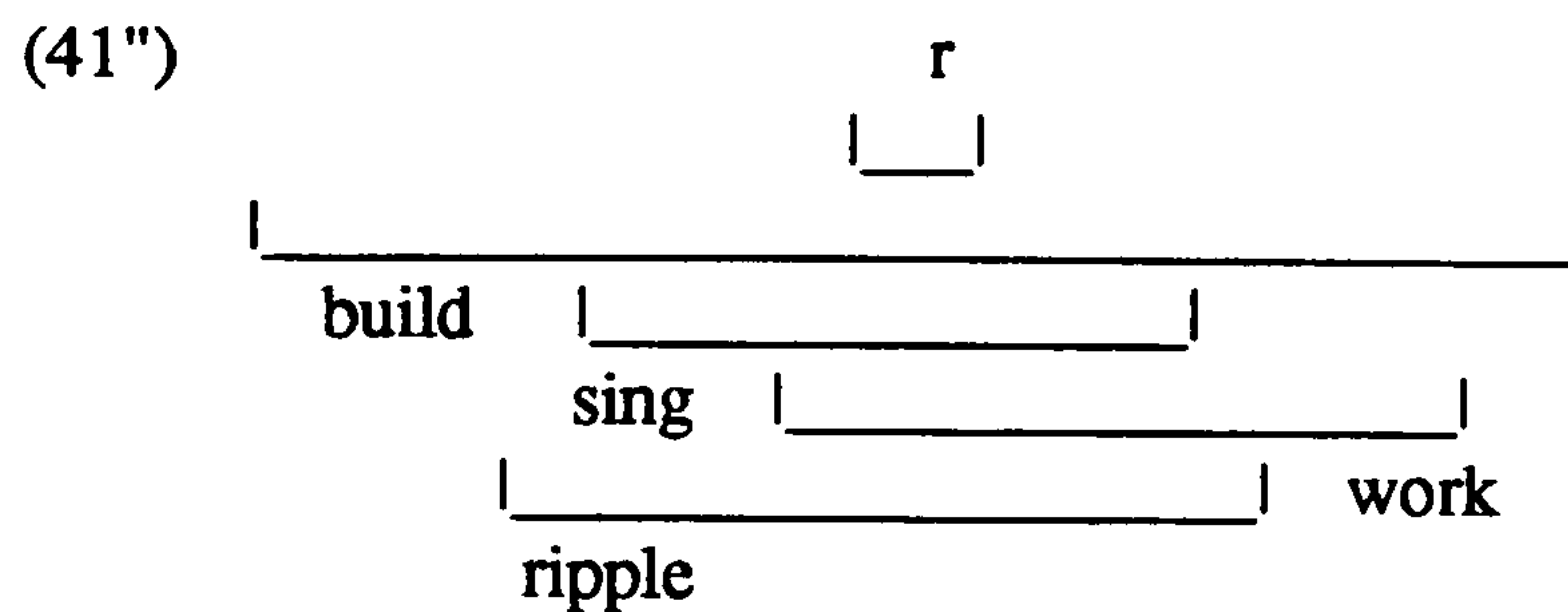
A more important problem area where reference times really come into play is formed by those expressions that are supposed to indicate a temporal overlap with the last mentioned event. Consider (41):

- (41) Jaime was building another boat. He sang happily as he
worked, the muscles of his brown arms rippled in the sun.

As Hinrichs (1986) points out, the expressions in (41) are "stative" in that they do not move the narrative forward. Obviously, this should be reflected in the discourse representation structure for this text. However, if the discourse representation rules that take care of expressions like these are formulated in a simple-minded way, merely stipulating that "stative" expressions describe events that temporally overlap with the last mentioned event - as was done for (40b) - then the resulting event structure could look like this:



Yet, the text in (41) clearly describes all the states of affairs as going on simultaneously, rather than just overlapping in pairs. Some notion of reference time is crucial to capture this part of the meaning of (41): a discourse representation rule is formulated stipulating that "stative" expressions surround the current reference time and do not update the reference time after they have been processed. For (41) this results in an event structure which can be depicted as follows:

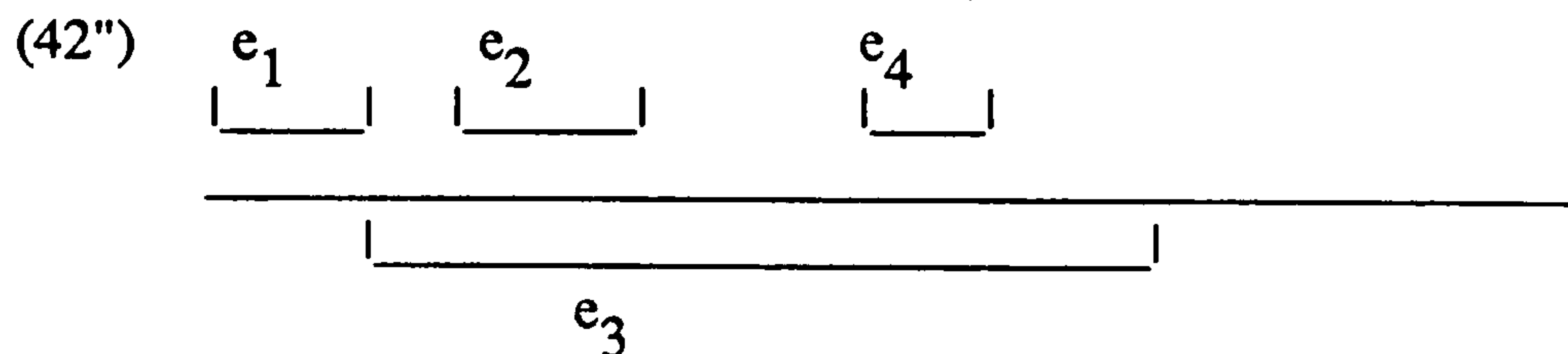


Applying these rules to a discourse like (42) would result in a discourse representation structure as in (42'), where \subseteq indicates temporal inclusion, and $<$ temporal precedence.

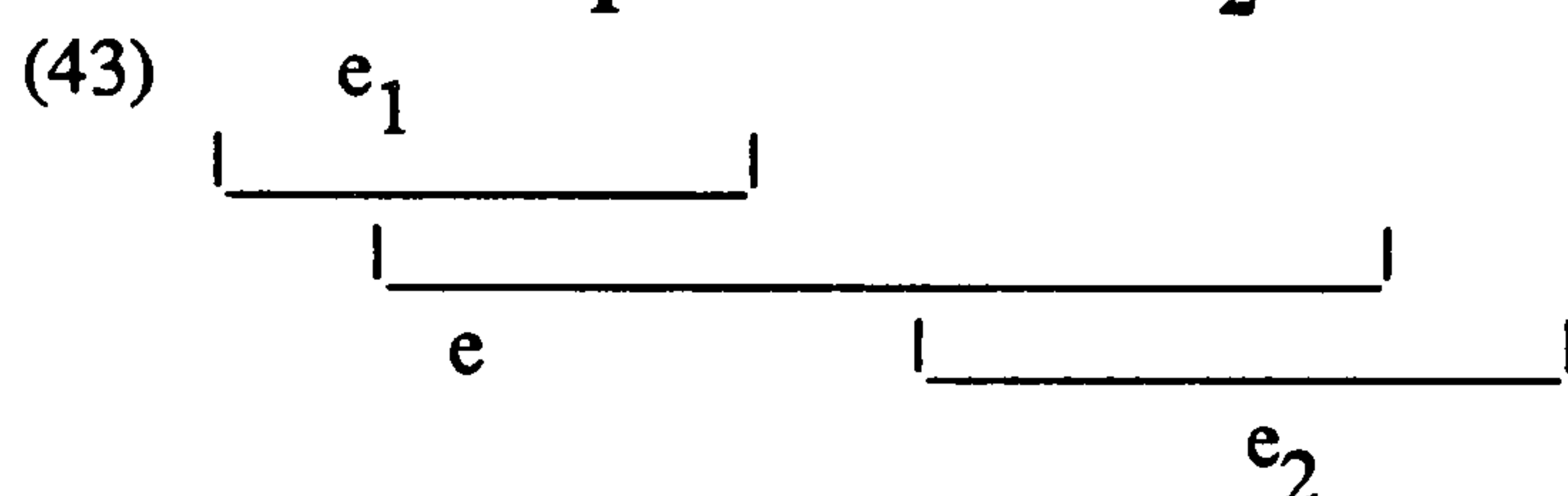
- (42) John turned the corner. He spotted Mary at the far end of the street. She was parking her car near a fire hydrant. He started shouting at her.

- | | | | |
|-------|-------------|-------|-------------------------------------|
| (42') | ro | | $e_1 = \text{John turn the corner}$ |
| | UI | | |
| | $e_1 < r_1$ | e_3 | $e_2 = \text{John spot Mary}$ |
| | UI | UI | |
| | $e_2 < r_2$ | | $e_3 = \text{Mary park her car}$ |
| | | UI | |
| | $e_4 < r_3$ | | $e_4 = \text{John start shouting}$ |

The structure in (42') is to be read in conjunction with further conditions which would appear in the complete discourse representation structure. It can be paraphrased as follows: e_1 is the event described as *John turned the corner*. Since this sentence contains a simple past, it is interpreted as having occurred at a contextually or co-textually specified time in the past, called r_0 . The simple tensed event e_1 introduces a new reference time r_1 later than e_1 . This reference time will be used for the interpretation of the next event, labelled e_2 . Since this event is also described in the simple past, it is supposed to have occurred within the current reference time, and sets up a new reference time r_2 . The next event, *Mary park her car* (e_3), is described by means of a progressive, which does not move the narrative forward. It is represented as surrounding the current reference time r_2 , and does not introduce a reference time of its own. The event *John start shouting*, also described in the simple past, is then interpreted with respect to r_2 , which is still the current reference time, and introduces a new reference time for possible continuations of the narrative. One of the many results that could emerge from mapping the event structure in (42') onto a time line is shown in (42'')



It is important to realize the rôle this mapping plays in Kamp's theory of the tenses. In Kamp's framework, an event can either overlap with another event or totally precede it. These relations can be used to define an underlying point structure (and this in turn can be used to create a period structure homomorphous to the event structure): if events e_1 and e_2 both overlap with an event e , and e_1 totally precedes e_2 , then e cannot be a point:



Kamp uses this machinery to explain the difference between the French *passé simple* and the *imparfait* (for present purposes, this distinction may be taken as analogous to that between the English simple past and the progressive): an event cannot be described by means of a *passé simple* if it takes place at more than one point in time. As Comrie (1976) argues, this way of talking about a perfective tense (like the *passé simple*) is slightly misleading in that the notion of point seems to preclude the possibility of the event having internal complexity or being extended in time. He therefore prefers to describe the semantic import of a perfective tense as reducing a state of affairs to a single "blob" (1976: 18): a perfective tense represents the state of affairs as a single object with clearly circumscribed limits and possibly internal complexity. Consequently, the difference between the perfective and imperfective constructions is not one of temporal duration, but merely one of how the state of affairs is represented.

This is exactly the idea Kamp captures by letting events do their work at an intermediate level. His definition of a point should not be thought of as necessarily mapping onto a punctual entity on a time line, but is more akin to Comrie's "blob". The stipulation that an event described by means of a perfective tense should be represented at the intermediate level by means of a point consequently does not imply that that event cannot be an extended one in the real world, only that it cannot have the relations of overlap described in (43) with other events mentioned in the discourse. The difference between perfective and imperfective constructions is thus not stated in terms of truth-conditions, but in terms of the construction rules for the intermediate discourse representation structure. We will return to the nature of these discourse

representation rules when discussing *when*-clauses and the temporal structure of discourse in general (chapter 6).

2.3. Non-referential approaches

All this, however, does not mean that the use of reference times is universally accepted. Proposals have been made to solve the puzzles mentioned in section 2.2.1 without taking the Reichenbach approach to tense semantics. Dowty (1979, 1982) and Richards (1982, 1986, 1987), for example, contain attempts to account for the interaction between tense and temporal adverbials without the use of reference times. Richards (1986) contains a similar account for constructions involving *when*-clauses. And Dowty (1986) proposes a general principle for the temporal interpretation of discourse that accounts for the narrative movement of time, also without resorting to the machinery of updating reference times.

Yet the techniques they resort to are, ultimately, not that different from the Reichenbachian approach and a convergence can be seen between the strictly quantificational and the referential approaches.

The interaction of tenses and certain temporal adverbials, which we showed in section 2.2.1 to be problematic for non-referential accounts, is handled in Dowty's (1979) approach by *not* treating tense and time adverbs as independent syntactic categories. Instead, they are introduced syncategorematically by a single syntactic rule, which - for an adverbial expression like *yesterday*, for example - takes a sentence, adds the adverbial at the end and changes the verb of the sentence to its past tense form. A worrying aspect of this treatment is that, if one tries to let logical form and surface form coincide as much as possible, tense and time adverbial should be looked upon as a single syntactic constituent (Dowty 1982: 28).

Dowty (1982) therefore proposes a different technique, due to Johnson (1981) and using a two-dimensional tense logic (cf. Kamp 1971). In this system, the definition of truth of a formula relative to a time of utterance *j* is given by means of the intermediate definition of truth relative to a pair of times $\langle i, j \rangle$. The index *i* plays intuitively the same role as Reichenbach's reference time, and *j* is much the same as Reichenbach's speech time. Tense operators do not shift the point in time at which a formula is evaluated - as Priorean tense operators do - but assert that the two indices *i* and *j* stand in a certain relation. The past operator, for example, stipulates that *i* is earlier than *j*. Temporal adverbials, which are treated syntactically as sentence operators, have the semantic effect of asserting that the reference time *i* is located at a

particular time. Thus, an expression like *yesterday* asserts that the reference time *i* is located at a particular time in the past, within yesterday. This allows tense operators to be nested syntactically within temporal adverb operators without producing the undesirable semantic effect that results with the nesting of Priorean operators illustrated in section 2.2.1. A sentence like (44a)

(44) (a) John left

comes out as true under Dowty's (1982) analysis if the index which represents the reference time is earlier than the speech time and John's leaving takes place at that reference time; (44b),

(44) (b) John left yesterday

will be true if the reference time is included somewhere in the interval referred to as *yesterday* and John leaves at the reference time.

A further similarity with Reichenbach's system can be found in Dowty's definition for the perfect operator HAVE. There, a third index is introduced, corresponding to Reichenbach's event time and allowing for an analysis of English perfect constructions on a par with Reichenbach's sketched in section 2.2.1.

This semantic system illustrates a convergence between the strict Reichenbachian approach and the Priorean quantificational analysis of tense. It borrows from the former the idea that a past tense does not just refer to some indefinite point in the past. The referential index *i* has a particular location, and the event is said to have taken place at that reference time. But it also takes over the Priorean idea that, in the case of a sentence like (44b), there is *some* time during that particular past period called *yesterday* at which the event took place, i.e. there is quantification over times, but those times are restricted to a particular past period.

A similar convergence of the Reichenbachian and Priorean perspective can be noted in Richards' (1986, 1987) proposals. His definitions for the tense operators are clearly Priorean, requiring there only to be *some* interval in the past (for the past tense operator) at which the tenseless sentence is true (Richards 1986a: 147). The treatment of temporal adverbials like *yesterday* or *at 9.0* is in essence similar to the double-indexing approach sketched before. A more detailed analysis and comparison can be found in Oberlander (1987).

The problem quantificational analyses have with the treatment of negatives as in

(45) I didn't turn off the stove

are overcome by postulating that sentences like these are in some sense (contextually rather than syntactically) "elliptical" for *I didn't turn off the stove then* where the deictic *then* is

interpreted as referring to a specific past interval (Richards 1986: 153-155).

Richards' approach is also interesting in that it addresses explicitly some of the problems of temporal phenomena in *discourse*: Richards (1987) contains an attempt to capture certain phenomena of temporal connection. Consider (46):

- (46) Yesterday, Max went home early. Later he came back to the office.

The second sentence in this discourse is represented by means of the sentential operator *LATER(e)* identifying the time of the "last mentioned" event, and specifying that the event in its scope occurred at a later time.

The difference between the strictly referential analyses of Kamp, Partee and Hinrichs, and the quantificational approach defended by Richards seems to be not as acute as one would expect. On the referential account, a simple past always involves reference to a particular point in the past. But, as was noted before, this formulation is too strong and has to be toned down for certain cases (cf. section 2.1). On the quantificational approach, the simple past does not involve reference to a specific point in the past, except in the case noted in (45) where Richards does have to introduce some kind of Reichenbachian device. Similarly, his treatment of the temporal connective in (46) is very similar in idea to the referential analysis presented by Kamp (1981, & Rohrer 1983), where the event last mentioned in the discourse acts as a reference point with respect to which the next event in the sequence is interpreted.

2.4. Problems with the referential account

From the preceding section it can be concluded that the referential approach does not have a monopoly on the formulation of an adequate account for some of the puzzles mentioned in section 2.2.1. But an even more damaging critique of the reference time approach could be mounted by singling out some of the puzzles that remain unsolved, although the Reichenbachian theory was actually designed to handle them.

In the area of tense and adverbial interaction, a number of constructions remain that a simple Reichenbachian analysis cannot account for. Consider (47):

- (47) (a) At 6 p.m, John built a house.
(b) The mountaineer reached the top in less than 5 hours.

A theory that simply situates event times and reference times as points on a time line will find it impossible to explain why (47a) is odd, or at best can only mean that John *started* to build a house at 6 p.m. Similarly, it will be hard to explain why the *in*-adverbial in (b) is understood

as referring to a period leading up to the event of *reaching the top*. What is needed, so it seems, is a more complex notion of "event time" that allows for this type of discrimination, and that - as an obvious correlate - allows for more intricate interaction patterns of event time and reference time than mere precedence or coincidence.

As for the problem of complex sentences, consider (48):

- (48) When the terrorists blew up the bank,
 they phoned a warning.
 they destroyed the whole building.
 they escaped in a van.
 they were caught by the police.

Clearly, the permanence principle of reference time will not be of much help to explain why in some cases the main clause event follows the event in the subordinate clause, sometimes precedes it and sometimes coincides with it. Ritchie (1979: 90) noticed the problem and suggested using a principle of "approximate coincidence" of reference times. But that will not help to explain the strangeness of (49):

- (49) ?When my car broke down, the sun set.

Again, it seems as if notions of (approximate) coincidence between points or overlap between intervals does not suffice to give an account of *when*-clauses. The type of referent set up by the *when*-clause in (48), for example, seems to be more complex than can be captured by purely topological notions. The implication of causality that seems to render (49) odd moreover seems to suggest that the extra structure that is needed is not even purely temporal in nature.

The principle of narrative movement of time also runs into problems with a discourse as in (50):

- (50) When John graduated, he threw a big party. He bought
 lots of booze and invited all his school mates.

Strictly speaking, once the event description *he threw a big party* is processed, the reference time is moved forward and subsequent simple past sentences are interpreted as describing events that occurred *after* the party. Clearly, this is not the intended interpretation of (50). Partee (1984: 260) acknowledges this problem and suggests that somehow the last mentioned events in a discourse like (50) should be taken to be part of the bigger event of *throwing a party*. Again, it is not clear by which mechanism this will be done in Partee's framework. The basics of the mechanism, however, seem to be that the second sentence picks up as its temporal antecedent the whole event described as *throwing a party*. This means that, again, what is needed is a more elaborate notion of temporal reference and of the nature of a temporal

In the previous sections, I defended the idea that tense is anaphoric in nature, in the sense that it is understood to refer to a definite time in the past, established by prior context or co-text. I tried to show that one way of accounting for this process of definite reference is by invoking a Reichenbachian conceptual apparatus, where reference times are used to mark the entity to which subsequent tenses can refer. I also showed that this account cannot deal with a great number of puzzles that have been plaguing tense semantics for a long time. The reason for this, I argued, does not lie in the nature of the referential account, but in the way these referential ideas were implemented. The problems are caused by using reference times and event times as simple and unanalyzed entities with relations of precedence or simultaneity between

them.

However, events and whatever we associate with them seem to be more complex than that. It seems, therefore, that what is needed to avoid the problems mentioned in this chapter is to study more closely the nature of the entity to which tenses anaphorically refer, and to design a theory of temporal reference which takes into account the internal structure of events and how this structure is described, for example, in *when*-clauses, by progressives, by certain adverbials, or by simple past sentences. Once it is recognized that an event cannot be regarded as an unanalyzed and unstructured entity, the notion of reference time will have to be reconsidered, and the question will have to be answered what it means to say that a reference time "coincides with" or "follows" this complex entity.

Using a theory of event structure to be developed in chapter 4, chapters 5 and 6 will give an account of temporal phenomena couched in this new ontology. Thus, rather than saying, for example, that the meaning of the *when* connective lies in the approximate coincidence or some other relation of two time points or intervals, it will be shown that *when* says something about the relation between two more complex event structures. Similarly, aspectual adverbials and auxiliaries will not be described as involving time points or intervals, but as pertaining to these more complex entities.

However, before outlining the nature of this event ontology, I will first discuss the place such an ontology has in the study of natural language phenomena. This will be done by comparing some of the characteristics of point, interval and event ontologies and discussing the arguments advanced in the literature for preferring one over the other. It is to this comparison that we turn next.

Chapter 3

Temporal Ontologies: Points, Intervals and Events

3.1. Introduction

In chapter 1 it was argued that a principled account of tense and aspect phenomena should be based on a proper treatment of the nature of temporal reference. A temporal referent, it was argued in the previous chapter, should not be thought of as an unstructured entity like a simple point or interval, possibly associated with an event, on a time line. The process of temporal reference seems to involve a more complex entity, the precise nature of which will be discussed at some length in following chapters.

In the present chapter I will briefly survey other work in the area of temporal reference. Since the claims I make in this dissertation are of an ontological or conceptual nature, the survey of theories offered here will be organised according to the temporal ontologies these theories assume.

The aim of the chapter is threefold. First, by examining the claims that were made in favour of or against certain temporal ontologies in other theories of tense and aspect, it will become easier to put in perspective the conceptual claims that will be made later in this dissertation. Secondly, in later chapters proposals will be made for the treatment of certain temporal phenomena using the new conceptual apparatus to be developed here. These proposals will be compared to existing accounts. Since most existing accounts are, however, couched in a different ontological framework, a comparison of particular applications often becomes rather complicated. Outlining in this chapter the basic tenets of those other frameworks will facilitate comparisons of particulars of different theories in later chapters.

Finally, apart from the puzzles mentioned in the previous chapter, there is one more problematic construction - involving certain uses of the progressive - that will be dealt with in later chapters. A comparison of existing temporal ontologies will allow for a statement of that problem in this chapter.

3.2. Points, intervals, events

Let us assume we want to build a Kripke semantics for temporal expressions in natural language. What is needed is a model, call it $\langle C, R, F \rangle$, consisting of a set of contexts (C), an accessibility relation between the contexts (R), and a function F which assigns a truth-value to every proposition letter p in every context $c \in C$. For a propositional temporal logic, the contexts will be whatever we take to be the basic temporal entities, and the accessibility relation will be the relation that holds between these temporal entities. The contexts and the accessibility relations can be defined differently within different conceptual frameworks, resulting in differing temporal logics.

The most common way of describing the basic temporal entities is as points without duration. The accessibility relation that can hold between them is that of precedence (assuming that simultaneity can be defined in terms of precedence relations). Properties of this precedence relation (reflexivity, transitivity, etc.) have been studied extensively; they obviously depend on the structure of the underlying time axis (does it have a branching past, is it modeled on the rational numbers, etc.). Slightly different temporal logics were developed by varying the properties of the precedence relation (cf. Rescher & Urquhart 1971).

Point ontologies have been associated mainly with Priorean temporal logics, the basics of which were introduced briefly in the previous chapter. Prior suggested that certain regularities in our use of the tenses could be formalized by introducing past and future time operators. A sentence like (52) can be represented as (52a) where the P stands for "at least once before now it was the case that":

- (52) John sang
(a) $P(\text{John sings})$

Other Priorean operators are F , meaning "at least once after now it will be the case that", and H and G , meaning "it has always been the case that" and "it is always going to be the case that" respectively.

Formal semanticists adopted this idea (cf. Kamp 1971; Rescher & Urquhart 1971) in their formulation of truth-conditions for natural language sentences: (52) is true now if there is a moment in time before now at which it was true to say "John sings" (meaning "John is singing"). Further study of linguistic structures revealed the need for more operators, such as Kamp's Now operator (Kamp 1971). Since point-based ontologies have had little to say about the kind of puzzles that will be discussed in following chapters, this short outline of its basic principles will suffice.

Many researchers have expressed unease at the use of points to represent time, objecting that it is too abstract a concept: a dimensionless point is a mathematical construct that is not encountered in everyday life, and it seems almost counterintuitive to treat the continuum of temporal duration by using durationless points. It is clear, of course, that these are pre-scientific feelings that cannot really be used as an argument against (or for) a scientific concept. As for the second objection, it is common topological practice to construct continuity out of dimensionless individuals.

There are, however, other and more serious objections to the idea that something is the case (or, in truth-functional semantics, that something is true) at a dimensionless moment of time. These problems mostly pertain to the instant of change (cf. Kamp 1980). Simply stated, it involves the question whether an object which changes in a certain respect, is in a pre-change or post-change state at the very moment of its change. If the answer is "both", the law of non-contradiction is violated; if the answer is "neither", the law of the excluded middle is violated.

Considerations like these have led researchers to

explore the possibility of replacing talk of [moments of time] by talk of those more robust, and hopefully less paradox-inducing entities, intervals or periods of time. (Humberstone 1979: 171)

The number of accessibility relations that can hold between these entities is far greater than for points: overlap, disjunctness, neighbourhood, co-start and co-finish are just some of the relations that have been described in the literature (Vilain 1982, Allen 1984, van Benthem 1983). When working with periods, it is also possible to perform operations that form periods out of other periods. Especially when one thinks of periods as sets (of smaller periods, or possibly points) one can use set-theoretic operations like conjunction, disjunction, intersection, union or complement for exactly this purpose.

But, returning to the rationale behind the interval option, it is interesting to note the words in Humberstone's quote: the decision to take periods instead of points as basic temporal individuals is based on the *hope* that it will avoid certain problems. It seems that the desire to change the time ontology from points to periods either stems from pre-scientific and intuitive feelings, or is caused by the discovery of a real logical problem in the point approach - the paradox of the moment of change - for which, however, it is not known whether the period alternative will provide a solution. In fact, as van Benthem (1983) shows, intervals do not provide a solution to this problem.

The point and interval approaches are in many ways each other's complements. We already mentioned the possibility of going from points to periods: by topologizing the point structure one can easily create an interval structure. One can also go in the other direction: points can be constructed as maximally intersecting intervals. This is a procedure already known to Whitehead, and more recently taken up by Kamp (1981) and van Benthem (1983). Because of these systematic connections, both approaches can be used at will. In fact, certain problems, such as temporal measurement and temporal continuity, are best approached *via* these connections (cf. van Benthem 1983: 81).

The period approach to temporal matters has become a very attractive enterprise in the study of language. The earliest and most influential proposals were made in Bennett & Partee (1972), Dowty (1979) and Kamp (1979).

One argument for choosing periods over points is that in language one never seems to refer to punctual, dimensionless entities. Even punctual expressions as in (53) do not single out the dimensionless entities of point logics but seem to refer, rather, to some more extended period - however short it may be:

- (53) At 6 o'clock sharp, Harry left the office.
At that very moment, the building collapsed.

But most arguments for taking intervals rather than points as basic in the study of temporal expressions revolve around the usage of certain aspectual adverbials in English. Consider (54) (cf. Dowty 1979: 138):

- (54) It took John an hour to draw that circle.

The truth of (54) depends on the length (an hour) and the location (the past) of the interval which John spends drawing a circle. That interval, however, cannot be defined as consisting of *moments* at which he draws a circle, i.e. one cannot construct that interval by collecting all the points at which it is true that *John drew a circle*. This "independence" of the truth of a tensed sentence at an interval from the truth of its constituent sentences at all moments within the interval cannot be dealt with in a traditional point-based logic. Dowty therefore suggests that a sentence like (54) should take truth-values with respect to an interval, not a point in time.

The argument in the preceding paragraph depends very much on the type of event described in (54): it extends in time but terminates at a particular, well-determined point in time, viz. the point at which John finishes drawing the circle. Because of this, the hour-long interval which

it took John to reach this point cannot be described as consisting of moments at which he reaches this finishing point. Yet a similar argument can be advanced to account for the usage of certain expressions that describe events *without* a particular point at which they terminate, such as *eat*, *walk* or *play the piano* (cf. Rescher & Urquhart 1971: 160; Dowty 1979: 139). Consider (55):

(55) Harry played the piano for two hours.

Again, the truth of this sentence depends on the length and the location of the interval during which Harry plays the piano. But that interval cannot be defined, Rescher and Dowty argue, as the maximal interval of moments at which he plays the piano, because the two-hour period referred to in (55) may contain points at which Harry is not actually playing, but turning the page, picking his nose or stretching his legs. One way of avoiding the problem would be to say that (55) is false just in case Harry was caught somewhere in that two-hour period taking a break from playing the piano. Alternatively, and closer to our natural language intuitions, (55) could be accepted as a true sentence in the circumstances just sketched. But this would mean assigning a truth-value to the expression *Harry play the piano* with respect to an interval, *independently* of the truth value of the sentence at the moments making up the interval. It is, again, this independence which is taken as an argument in favour of taking truth with respect to intervals as basic.

Kamp (1979: 392-393) also argues along similar lines. Consider (56):

(56) Jeffrey always writes his novels in less than a year.

The truth of this sentence depends on the length of the intervals which Jeffrey spends writing novels. But such an interval cannot be defined as the maximum interval consisting of moments at which Jeffrey is writing a novel. If, for example, he starts a novel on January 1, starts another one on June 15, finishes the first one at the end of September and finishes the second one at the end of May of the following year, then there will be a continuous interval of instants at which Jeffrey is writing a novel which has a duration of 17 months. As a consequence, (56) would come out - wrongly - as false. The way to remedy this is to assume that the predicate *writes a novel* receives a truth-value with respect to an interval in time, viz. an interval for each novel written. For the truth of (56), one would need a further stipulation that each of these intervals lasted less than a year. Again, intervals should be taken as basic entities in the assignment of truth values.

The crucial point in these arguments is that the truth of a statement with respect to an interval is independent from the truth of this statement with respect to the moments making up the

interval. This point is reminiscent of the principle of heredity over periods. The point of discussion there is whether a statement, when true with respect to an interval, is true with respect to all subintervals. In a heterogeneous logic like Dowty's (1979, 1986) this is only the case for expressions belonging to certain classes. Consider (57):

- (57) (a) John was ill
(b) John drew a circle

According to Dowty, if (a) is true with respect to a certain interval, then it is true at every subinterval that *John was ill*. If, however, (b) is true with respect to a certain interval then it is *false* at every subinterval that *John drew a circle*. The expression in (b) is said to belong to a different class, and this type of sentence is not hereditary over periods. However, homogeneous interval logics have been developed for natural language (cf. Richards 1986). Richards would claim that, if (57b) is true with respect to an interval, then there is an interval in the past with respect to which the tenseless expression *John draw a circle* is true. And this expression will automatically have to be true with respect to all subintervals of that interval. This works out in Richards' theory because tenseless expressions do not necessarily have the same aspectual category as tensed expressions. This seems to indicate that the issue of homogeneity versus heterogeneity is a theory-internal one, depending crucially on the nature of the formulae that are assigned truth-values; in chapter 7 I will return to Richards' notion of tenseless propositions. Suffice it to note here that the choice between a homogeneous or heterogeneous logic can be made independently of the arguments raised in favour of interval-based approaches. In fact, if it were not independent, then arguments in favour of an interval-based approach would force one into a heterogeneous logic, making a homogeneous interval logic a logical impossibility. Work done by Richards (1986) and Oberlander (1987) shows that it is possible to construct a homogeneous interval logic.

Yet, the interval approach also has certain drawbacks. One of these is the lack of testability (cf. Parsons 1984). In ordinary tense logic, it is an intuitively simple matter to decide whether a sentence is true at a certain point in time. In interval semantics, this issue seems to be more complicated. *Max has been here for an hour* is true if there is a one-hour interval at which Max was here. *Ralph taught for a year* can be true even if Ralph didn't teach during the three-month summer vacation. *John attended the meetings for a year* can be true, even if the meetings took place only once every two months, but not if they were held weekly in December only. As Vlach (1981a:275) points out, one can - and for a proper analysis of English may well have to - distinguish between truth *at* an interval, truth *for* an interval and truth *in* an interval. So, although periods of time are taken to be the basic temporal entities, the internal structure of periods clearly comes into play. The necessity of taking into account the

internal structure of intervals, and the consequences of not doing so, can be observed by inspecting some of the technical definitions in early interval work. Consider, e.g., Dowty's definition for "move" (cf. Parsons 1982: 294):

x moves is true at an interval I iff x is located at a place p at the beginning of I and x is not located at p anymore at the end of I. (after Dowty 1979: 169)

Now, suppose there is an object moving back and forth between two points, or a person running around a track two or three times - intuition would tell us there was movement in both cases, yet the object and person are in exactly the same place at the beginning and at the end of the interval. According to Dowty's definition, the statement *x moved* is false in I, even though it was true at every instant of I. So it seems there was movement *throughout* the interval, yet there is no way of saying whether there was movement *at* the interval. The reason for this discrepancy is that we do not have clear intuitions about what the theoretical notion of movement or (more generally) truth with respect to an interval refers to.

One can, moreover, cast serious doubts on the arguments given in favour of taking intervals as the basic temporal entities in a description of language. What Dowty's, Rescher's and Kamp's examples illustrate is that truth of a statement with respect to a period cannot be determined from the truth of that statement with respect to the parts making up that period. They then conclude that the extension of an expression like *draw a circle* or *play the piano* cannot be exhaustively described as a function which associates individuals with instants. Yet, as Tichy (1985) argues, it is also not clear that the event of *writing a novel* in (56) is captured by associating individuals with uninterrupted *periods* during which an individual succeeds in completing a novel. Novels can be written in bits and pieces, which would mean associating individuals with sets of broken and unbroken intervals. Tichy argues that an adequate description of novel-writing events should take the form of a function associating each individual not with the time stretches he spends writing but with the *behaviour* which amounts to his writing a novel (Tichy 1980, 1985).

Arguments in favour of using such a more complex entity (usually referred to as *events*) in the study of tense and aspect have been around for some time now. These arguments are often very similar to the rather intuitive arguments that were given in preference of intervals over points: events are more concrete and "easier to understand [...] than various abstract properties of time" (Bach 1981: 69); events come first in our experience of the world, and it seems therefore plausible to assume "that the nature of time is determined by the temporal connections of the events which constitute the history of our universe" (Kamp 1979: 382).

Again, these are not very convincing arguments. The fact that events are basic in our experience does not mean they should be basic in *theories* of our experience. Also, it is not entirely clear that events *are* basic. One could argue that our experience is one big event; chopping it up into smaller units that can serve as theoretical primitives may be just as abstract and arbitrary a choice as taking points or intervals as basic. Moreover, the argument is again focussing on time descriptions, rather than on requirements from a natural language point of view.

Tichy (1980, 1985) was probably one of the first to use linguistic arguments to argue in favour of taking events as basic in a theory of natural language temporal relations. His criticism of intervalist arguments has already been discussed briefly above. But he argues that the inadequacy of the interval approach is most striking when one is dealing with interrupted behaviour, as illustrated in (57):

- (57) (a) John was reading a novel when he fell asleep.
- (b) Ludwig died while he was writing his tenth symphony.

The meaning of these progressive constructions cannot be captured by associating individuals with time intervals: the class of intervals associated with John, for example, will only contain intervals during which he reads a whole novel. And in (b), no interval can be associated with Ludwig during which he wrote his tenth symphony, since that symphony was never completed.

It is obvious, however, that the duration of the event described in (57b) is the initial segment of the interval during which Ludwig wrote a completed tenth symphony in some other possible world, and what makes (57b) true is that Ludwig displayed certain behaviour just before his death which can be completed into a not-realized symphony-writing event. This idea cannot be implemented formally, if the extension of *write a symphony* is represented by associating individuals with classes of intervals rather than with classes of events.

Tichy therefore proposes that statements like *write a symphony* should be analyzed as involving reference to relations between individuals and events. Each event uniquely determines the time stretch it takes up, which is the running time of the event. A sentence like (57b) would be true if Ludwig stands in a certain relation to at least one symphony-writing event (not necessarily realized) during the running time of which he died. The earlier discussed example *John took an hour to draw a circle* would be true if at least one circle-drawing event can be found with a one-hour long running time and to which John stands in a certain relation. A definition like this could easily be refined to capture sentences like *John drew a circle no more than once yesterday* (Tichy 1985). What Bennett, Partee, Dowty and Kamp showed was that intervals play a role in analyzing sentences. What they did not show is that these intervals

should be the basic entities in a (truth-conditional) semantics of temporally referring expressions.

So far, Tichy's proposals seem very close to an interval-based approach. But Tichy goes further. He suggests taking into account the internal structure of events, more specifically their developmental phases, from preparation over upshot to possible consequences (Tichy 1985). A similar proposal had been made independently by Freed (1979), Johnson (1981) and Steedman (1981), although there it was stressed that these different phases should be thought of as different possible perspectives on one and the same event. It is this approach which will be further developed in chapter 4.

More recently, other proposals have been put forward in the linguistics literature to build theories of tense and aspect (and other phenomena, such as adverbials) which take into account the internal structure of events (Meulen 1982, 1984; Carlson 1983; Cooper 1985; Hinrichs 1986; Bach 1986). They try to account for the imperfective use of the progressive by specifying the relation that holds between the incomplete event (as described by the progressive) and the complete event (as described by the simple past sentence). This idea necessitates the introduction of a more complex structure on the domain underlying the meaning representations: it is not enough just to take monolithic events as basic entities in the semantics. What is called for, rather, is an ontology in which events can be decomposed into their constituent parts or assembled into more complex events.

A similar problem had been noted before in the nominal domain: one would like one's semantic theory to be able to give an account of why it is possible that both (58a) and (58b) are true.

- (58) (a) All the gold in this ring is old.
(b) This ring is not old.

To accomplish this, it is necessary to base one's semantics on an ontology in which individual entities can be broken up into their constituent parts, or be assembled into bigger entities. Link (1983) suggests such an ontology. His analysis of bare plurals and mass nouns uses a model consisting of a set of ordinary individuals *A* (as in the standard interpretations of predicate calculus or Montague grammar). By means of a join-operation, this domain is extended into *E*, which also contains plural individuals: if *Harry* and *this chair* are both members of the domain, then the plural individual *Harry and this chair* is also an element of the domain. Finally, the model also contains the stuff making up the material extension of all the individuals in the model. A special subset of this, called *D*, contains all the stuff that makes up specific individuals. Thus, it would contain all the stuff that makes up Harry, and all the stuff that

makes up the chair. This subsystem has its own join and its own partial ordering, such that it becomes a complete join-semilattice. Link shows that this is exactly the kind of structure that is needed to capture the notions of cumulative and distributive reference one wants to capture when dealing with mass nouns and bare plurals (and about which more in chapter 7).

This strategy was adapted by Bach (1986) to fit the domain of event descriptions. His model contains atomic events (corresponding to singular individuals), plural events (such as *John fell and broke his nose*; this corresponds to Link's plural individuals) and processes. Processes are considered to be the stuff that make up events. This allows him to state rules to the effect that the "stuff" (or processes) making up the event described in (59) are part of the processes making up the event in (60):

(59) John wrote a chapter.

(60) John wrote a book.

The imperfective puzzle, Bach proposes to solve along the same lines. A sentence like

(61) John was crossing the street

indicates that certain processes have occurred which form part of the processes that occur when John crosses the street, without assuming that the latter event actually occurred. The criteria for deciding what these processes look like is no part of linguistics, Bach argues.

Hinrichs' (1985) lattice-theoretic approach to aspect and Aktionsarten is similar to Bach's. The difference is that he uses the notion of event-stage instead of Bach's processes to describe the material making up events. This notion of stage is borrowed from Carlson's semantics of bare plurals and mass terms (Carlson 1977). In that account, stages were used to denote a spatially and temporally bounded manifestation of something or someone. Thus, when someone asserts

(62) Max is brushing his teeth

that person is not really predicating something about the whole of Max, but about a particular spatio-temporal instantiation of Max. As Carlson notes, stages of individuals are closely related to events - they are not just a film clip of someone's life, but are more akin to things that *happen* (Carlson 1983). Details of how Carlson uses this notion to give a semantics of bare plurals and mass nouns need not concern us here.

Hinrichs transferred the notion of stage from the nominal domain to the verbal domain. His semantics uses a model consisting of individuals as well as spatio-temporal locations. These locations are partially ordered with respect to certain temporal and spatial relations such that the set assumes the structure of a complete join-semilattice - exactly the structure that Link

showed is needed to capture notions of cumulative and distributive reference in the nominal domain. The translation of a sentence such as

(63) Harry slept

will come out as specifying that there is some individual stage of Harry which stands in a sleep relation to some event-stage of an individual event of sleeping.

Although this approach to tense, aspect and Aktionsarten is still fairly new, Hinrichs (1985) already accounts for an impressive fragment of English. Yet, although a treatment is offered for notorious puzzles such as the imperfective paradox, it is not clear how this account can be extended to include progressives of achievements. A progressive achievement should refer to the realization of some of the processes (or some of the event-stages) that normally constitute such an achievement. However, achievements are not normally thought of as having such event-stages associated with them. From the discussion earlier on in this chapter, it should be obvious that the solution lies in setting up the account in such a way that the progressive will pick out the processes *leading up to* the achievement. One of the arguments to be developed in later chapters concerns how this can be done in a principled way. Thus, the account offered here is not seen as adversative to the Bach and Hinrichs approach, but rather as an explication of the kind of conceptual structure these researchers have already started to formalize.

There are, of course, many other proposals in philosophy, linguistics and Artificial Intelligence using events as their basic ontological category. Davidson (1967) constitutes undoubtedly the most influential of these proposals: he suggests treating events as concrete individuals. Natural language sentences are represented with quantified variables ranging over events. Davidson also considered in depth the problem of how events can be individuated by taking into account their causes and consequences. Davidson did not introduce this ontology to give an account of temporal constructions, but to solve certain puzzles in the treatment of manner adverbials. In chapter 5, however, we will come across a Davidsonian treatment of some tense and aspect phenomena when discussing the work of Parsons (1984).

Another reason why philosophers have suggested the use of events as basic in a natural language semantics is an unease with the so-called "weakly intensional" (Chierchia & Rooth 1984) approach to events. As was discussed before, in this approach - essentially the Montague tradition - events are defined as pairs of worlds and times. This leads to the puzzle, probably first noted by Cresswell (1974), that such a theory cannot accommodate two events which are true at exactly the same set of times in every possible world and are nevertheless

distinct. Because of this, it was suggested not to conceive of events as properties of times but as semantically primitive entities. In this so-called "strongly intensional" treatment of events - essentially the Davidsonian tradition - events are assumed to be located in space and time but are not reduceable to them. This makes it possible for two events to always occur at the same time in all possible worlds and still to be distinct. As a result, the accessibility relations between events in an approach like Kamp's still need only be those that normally hold between intervals - i.e. precedence and overlap. Yet such an approach gains in expressability in that two events can hold at the same time and still be different, whereas two intervals that hold at the same time have to be identical.

In Artificial Intelligence, the use of events is mostly associated with McDermott (1982), who thinks of them as classes of intervals selected from various possible histories of the world. This type of work will be returned to in chapter 8.

Many of the issues that concerned Davidson and McDermott, especially those that deal with the individuation of events, are not touched upon in subsequent chapters. Suffice it to say that, as far as individuation of events is concerned, I will lean more towards the Davidsonian view and will regard events as embedded in a network of causes and effects, than to McDermott's practice of individuation through temporal location. This, however, is not a decision made on the basis of certain beliefs about the world, but is dictated by the analysis of temporal expressions as carried out in subsequent chapters.

3.3. Conclusion

In this chapter I have tried to show that there are no *a priori* reasons for choosing intervals over points or events over intervals in a temporal ontology: the arguments advanced in the literature are often based on intuitive feelings or are irrelevant to the study of language. I have also tried to show that the three ontologies should be seen as complementary rather than adversary: an event is assumed to have a running time which is most easily represented as a time period, and from these periods points can be reconstructed.

There are, however, good arguments emerging from an analysis of natural language constructions to assume that events should be taken as basic. Some of these constructions were already mentioned in this chapter and the previous one, and will be treated at some length in following chapters. I shall here just briefly review some of this evidence and map out the shape of future chapters.

It was noted in chapter 2 that sentences with *for* and *in*-adverbials constitute a problem for a simple-minded analysis in terms of reference times and event times. In the current chapter, it was noted that this problem had been recognized in the literature, and the suggested solution was to take intervals as the basic entity on the basis of which a semantics of temporal constructions should be based. Tichy was quoted as disputing the validity of the arguments underlying this decision. Ignoring for the moment whether Tichy is right in his criticism, it will have to be shown that an event-based account like the one to be presented here has at least the same explanatory power as interval-based theories. That this is indeed the case will be shown in sections 5.1 and 5.2.

Progressive constructions were also mentioned in chapter 2 as creating a problem for a simple-minded Reichenbachian analysis. Interval approaches have achieved some degree of success in accounting for these constructions, but they cannot be extended to give a semantics for progressives describing interrupted behaviour. In chapter 5, a major section will be devoted to this problem, including an extended comparison with existing interval and event-based approaches.

In the previous chapter, perfects were also singled out as receiving a rather unsatisfactory treatment in Reichenbachian terms. Interval semantics has had little to offer on this score, Heny (1982) and Richards (1982, 1986) being notable exceptions. In section 5.4 a treatment will be given of this construction, as well as arguments why - again - an account purely in terms of intervals will not be able to capture what it should be capturing.

Next, temporal connection and the temporal structure of discourse will be examined from this new perspective. As was shown in chapter 2, a Reichenbachian treatment should be well-suited to account for these phenomena, yet even with the modifications suggested by Partee and Hinrichs and discussed in chapter 2, many problems still remain. They will be taken up in chapters 6 and 7.

But before we attempt a detailed examination of all these issues, it is important to first sketch in general terms the nature of the referential account to be developed here. It is to this that we turn next.

Chapter 4

A typology of temporal descriptions

4.1. Introduction

It emerged from the previous chapters that the starting point for a principled semantics of temporal expressions should be a study of the internal structure of events and of the ways in which a language user can describe various subparts of events. In this chapter, such a study will be carried out. This will result in a taxonomy of event descriptions, reflecting the temporal profile of the event descriptions and accounting for the contribution they make to the temporal structure of the sentence or discourse they appear in. This type of work is usually associated with the classification given by Vendler (1967), although it is part of a long tradition started by Aristotle, and nowadays found in work by Verkuyl (1972), Taylor (1977), Dowty (1979), Mourelatos (1981) and many others.

It is not entirely clear what the place is of classifications like these in traditional linguistics. They involve the traditional notion of aspect, and are often referred to by the term "verb aspects" (e.g. Dowty 1979: 52). Yet, sometimes this sort of taxonomy is seen as clearly different from aspect (e.g. in Klein 1974), and then the older term "Aktionsarten" ("types of actions") is used.

In the taxonomy I present, I will be using concepts both from "classic" linguistic treatises on aspect (notions like "concluded" or "ongoing") as well as concepts from Vendler's original system of Aktionsarten. Moreover, in the "aspectual" system presented here, tense will also play a crucial role. Such a unified approach to tense, aspect and Aktionsarten may seem in sharp contrast with traditional accounts in the area of temporal reference, where these categories are treated as clearly separate. To defend why I think such a unified approach is, nevertheless, both necessary and possible, a short digression on the basic concepts of tense, aspect and Aktionsarten seems useful.

4.2. Tense, aspect and Aktionsarten

It was argued in the previous chapters that the processing of temporal information in language can be described as the construction and continual update of a structured model of the states of affairs talked about in the discourse. What we are trying to determine is what apparatus



language users have at their disposal to convey information about how states of affairs are ordered with respect to each other or with respect to a chosen point in time, and what clues are available to the language user to extract this information from natural language discourse.

In most languages, there are at least two ways of expressing temporal relations, viz. lexicalization and grammaticalization (for this distinction, see Lyons 1977: 234-235). The importance of lexicalization for the expression of temporal information was already pointed out in chapter 1: words from almost any word class can be used to express temporal information. But languages very often also have grammatical forms to express temporal information, for example in the form of affixes on the verb. Ordering information is then usually given with respect to a well-defined point on the time line, for example the moment of speech. Such languages are said to have tense.

Information about how states of affairs are ordered with respect to each other can also be given indirectly, however, namely by referring to the (internal) temporal structure of a state of affairs. Deciding what the temporal relation is between two states of affairs involves, amongst other things, determining what the structure is of these states of affairs, since the number and type of relations two complex states of affairs can have with respect to each other are different than those that can hold between two simple states of affairs. The linguistic apparatus for establishing this is usually referred to by the name of aspect.

As is the case with temporal differences, aspectual differences can also be realized in two ways. They can be grammaticalized, for example, as aspectual affixes on verbs; it is these grammatical categories that are usually referred to as aspect proper. But aspectual distinctions can also be present in lexical material: *win the race*, *work in the garden*, *build a house* and *know the answer* differ, for example, as to whether they take time or not, or whether they have a final point associated with them. Classes of verbs, reflecting the aspectual distinctions they express, are usually referred to as "Aktionsarten".

In its original sense, aspect only refers to the opposition between perfective and imperfective descriptions of events, representing states of affairs either as accomplished or not. However, the notion of aspect has gradually been extended to cover a variety of other notions (duration, instantaneity, frequency, initiation, completion) in so far as these are grammaticalized in the structure of particular languages (Lyons 1977: 705). The difference with Aktionsarten - which is also involved with notions like duration, instantaneity or completion - lies in the fact that the

latter category only pertains to the lexicalizations of these distinctions. The problem is, however, that it is not clear what counts as grammaticalization of aspectual distinctions and what counts as lexicalization. To express that a state of affairs occurred repeatedly, for example, one can use the expression *used to*; if one wants to indicate that the middle of a state of affairs is referred to rather than the beginning or end, one can use the progressive auxiliary in English. Researchers differ as to whether these are grammatical forms or lexical items. As Dahl argues (1985: 27), according to the current definitions of aspect and Aktionsarten, Russian aspect (the perfectivity-imperfectivity distinction) should be categorized as Aktionsarten rather than aspect.

Moreover, there are languages where certain aspectual distinctions can be expressed by means of prepositions. In the German example (64), for example, there is an implication that Gerhard finished reading the book; (65) doesn't have this implication.

- (64) Gerhard las das Buch
"Gerhard read the book"
- (65) Gerhard las im Buch
"Gerhard read in the book"

A similar contrast can be found in some English constructions:

- (66) He walked to the station.
He walked towards the station.

This indicates that the lexicalization of aspectual differences involves more than just a classification into Aktionsarten.

Finally, as we will see later on, there are systematic restrictions on the possible co-occurrence of certain "real" aspectual markers (like the perfect auxiliary in English) with verbs from certain Vendlerian categories, as witnessed in (67):

- (67) *He has just wanted a toy.
?He has just worked (in the garden).
He has just reached the top.

What is needed is a system that does not study aspect in isolation from Aktionsarten. In fact, although Comrie (1976) sees aspect as clearly distinct from Aktionsarten and professes to study only the former, his aspectual system has been argued to be a blend of the two traditions (cf. Bache 1982).

Most recent attempts to distinguish between aspect and Aktionsarten do this in terms of a subjectivity versus objectivity opposition. Aspect is defined as a *subjective* choice between describing a state of affairs as completed or not; Aktionsarten are supposed to be an *objective* classification, reflecting the duration of states of affairs (Houweling 1985). In what follows it

will be argued, however, that also an "objectively punctual" state of affairs can, in certain circumstances, be described as extended - and *vice versa*. In fact, in the taxonomy to be developed here all the distinctions will be taken to be "subjective" in that they are ways of describing the world, rather than being a classification of real world events. I will return to this point in section 4.3.

To summarize, the fuzziness of the distinction between the systems of aspect and Aktionsarten as well as their systematic correlations are good arguments in favour of trying for a unified account incorporating both systems. Following Lyons (1977: 706), I shall use the term "aspectual character" to refer to the temporal profile and the other (temporal) characteristics of expressions, on the basis of which they are assigned to a class in the taxonomy. The taxonomy will be set up in such a way that the links with traditional aspectual categories as well as the role of other lexical material can be accounted for in an elegant way.

It should also not come as a surprise that in this classification of event descriptions tense plays a role as well. Even though grammarians have always been at pains to distinguish the two (cf. Comrie 1976 and 1985), they have at the same time been equally at pains to point out that the relations between tense and aspect systems are far from arbitrary (e.g. Lyons 1968: 316). Consider:

- (68) (a) John wrote a good book.
(b) John writes a good book.

The example in (b) will be interpreted as expressing a dispositional or habitual state of affairs, whereas (a) will normally be interpreted as a description of a one-off event. It is clearly the difference in tense which accomplishes this aspectual distinction. Again, the taxonomy I propose here will be set up in such a way that interactions like these can be accounted for in a straightforward way.

Lastly, most of the traditional works on tense have overemphasized the importance of time in their enterprise. In Comrie (1985) for example, tense is defined as "the grammaticalization of time" (1985: 6). This definition is then taken as a starting point to decide what languages have tense, and tenses are only studied in so far as they say something about temporal relations. In many respects, the line of research I take is the reverse of Comrie's: I try to give an account of the apparatus of tense, aspect and related categories. In doing so, it will become clear that *other* than purely temporal notions play an important role in such an account.

4.3. The taxonomy

Since Vendler’s work (1967) is still the best known of aspectual taxonomies, it is a good idea to take it as a starting point. His original classification can be represented schematically as follows:

<u>processes with successive phases</u>		<u>processes without successive phases</u>	
homogeneous	heterogeneous	punctual	period
activities	accomplishments	achievements	states
run, swim, push a cart, walk	paint a picture, write a novel, read a book	recognize, win the race, find, realize	love, know, believe, want, resemble

Figure 1: Vendler’s taxonomy.

Activities and accomplishments are defined as processes that extend in time and have successive phases; both can occur with a progressive auxiliary.

- (69)
- John was walking.
Harry is reading a book.

Accomplishments can be distinguished from activities in that the former have an intrinsic conclusion, whereas the latter go on in a homogeneous way. The difference can be brought out by means of certain adverbial expressions. Activities, like *walk*, can occur freely with a *for*-adverbial, indicating how long the homogeneous activity went on for. Accomplishments, like *write a novel*, combine most naturally with an *in*-adverbial, indicating the time needed to reach the point of conclusion.

- (70)
- John walked for an hour or so.
Harry wrote that novel in less than a month.
*John walked in 15 minutes.
*Harry built a house for two days.

In Vendler’s scheme, achievements and states do not have successive phases and do not combine with the progressive auxiliary.

- (71)
- *Harry is knowing the answer.
*John is recognizing his father.

The difference between the two aspectual classes is that achievements are instantaneous, whereas states describe rather indefinitely extending periods. This difference can, again, be

brought out by using certain adverbials.

- (72) At that point, Harry recognized his father.
I believed in Santa Claus for many years.
*At 3 o'clock, Harry believed in Santa Claus.
*For several hours, Harry reached the top.

It is important to note here that it is often possible to think of a context where the starred sentences do have an interpretation. Vendler's claim is that in these cases we are dealing with a derived or secondary meaning of the expression under consideration. I will discuss this phenomenon rather extensively later on, since it forms an important part of the philosophy behind the taxonomy I am developing here.

Scores of researchers have proposed additions and changes to this basic scheme. Some introduced new categories (Leech 1971, Platzack 1979, Galton 1984). Some reduced the number of categories (e.g. Parsons 1984). Sometimes, certain verbs were reclassified: Mourelatos (1981) contains an elaborate discussion of what category perception verbs belong to. Others still devised new and more elaborate tests to determine the aspectual category of an expression (eg. L. Carlson 1981, Freed 1979).

The decision to remove or add categories depends strongly on what exactly one wants to accomplish or account for with the taxonomy. Kenny's (1963), Vendler's (1967) and Nordenfelt's (1977) taxonomies, for example, were devised to be used as the basis for a logic of action. This means that they contain distinctions reflecting whether certain actions are under the control of an agent or not. Leech (1971), on the other hand, tries to give a finely tuned account of semantic differences between verbs, introducing categories like verbs of inert perception, verbs of bodily sensation, etc. Such distinctions may be useful in these approaches, but need not necessarily be of great use when developing a theory of temporal relations.

Because of this, the details of all these different approaches and the changes that have been proposed for Vendler's original scheme need not concern us at the moment - although when presenting my aspectual classification I will make use of criticisms and ideas that surfaced in the taxonomic literature. At the moment, I will concentrate on the differences between the taxonomy to be presented here and a classification like Vendler's.

One difference with Vendler's original taxonomy is that the classification developed here has an extra category. As was pointed out before, adding or removing categories to classifications like these is dependent on what one wants to achieve with them. The fact that the taxonomy

put forward here has five categories rather than some other number is only an indication of the fact that, for purposes of the description of temporal relations, the five different categories seem to suffice. Should it emerge in future research that more or fewer categories are needed, this would not constitute a criticism of the core principle of the taxonomy: the *mechanism* or dynamics I describe using the five categories is more important than the actual *number* of categories used in the taxonomy.

Vendler’s nomenclature has also been replaced entirely. One reason is that his original terminology is not very transparent, and carries a lot of implications of intentionality which are better avoided. As will emerge later, the nomenclature used here was chosen to reflect a hypothesis concerning the mechanisms underlying the taxonomy.

The aspectual classes and the terminology that will be used here can be represented schematically as follows:

	EVENTS		STATES
	atomic	extended	
+conseq	CULMINATION recognize, spot, win the race	CULMINATED PROCESS build a house, eat a sandwich	understand, love, know, resemble
-conseq	POINT hiccough, tap, wink	PROCESS run, swim, walk, play the piano	

Figure 2: The new labels of the 5 Vendlerian categories

This taxonomy makes a clear distinction between state-like temporal descriptions and all the other categories, labelled "events". At the moment, states only comprise the verbs usually referred to as stative verbs; we shall see later that this category includes additional categories. The distinction between states and events plays an important role in other parts of the theory.

Events will be referred to as "bounded" in that they are supposed to start and end at relatively

precise points in time. States are "unbounded" since - although they seem to extend in time - no reference is made to their start and end points. *To be tall*, for example, is something which one is at a certain point in time, without it being very clear at which point one begins or ceases to be in this state - although contexts can be imagined where such transitions would be sudden and easy to pinpoint.

In the category of events, a distinction is made between events that are extended and those that are not, reflecting the distinction made by Vendler between events that have successive phases and those that do not.

Within each of these event-categories, a further distinction is made between events that have consequences and those that do not. It is more common to refer to these categories as telic and atelic. Telic extended events are events that go on in time until they reach a particular and well-defined point. Once the terminal point is reached, a change of state takes place; the changed state will be referred to as the consequences of the event. They can be described by means of a perfect. Thus, the expression *John built a house* describes a particular state of affairs as extended in time and leading up to a point in time at which a change of state takes place. The associated consequences, whatever they are, can be referred to by means of a perfect as in *John has built a house*. Atelic extended events extend in time without such a final point. Because of this, they do not allow reference to consequences, as can be seen from the infelicity of *I have just worked in the garden*. Of course, *I have worked in the garden* can be used felicitously, for example in the case where *work in the garden* describes a particular job that had to be carried out. In this context, *work in the garden* has a particular terminal point associated with it; the perfect can then be used to refer to the consequences associated with this telic event.

The distinctions made so far allow us to distinguish "processes" (Vendler's activities) from "culminated processes" (Vendler's accomplishments). Within the group of atomic events a similar distinction can be drawn. "Culminations" (Vendler's achievements) are unstructured events that constitute a final point of their own; "points" constitute a category, not recognized by Vendler, of atomic events without consequences (cf. the non-conclusive, punctual events in Quirk e.a. (1985:201), and earlier proposals in Miller & Johnson-Laird 1976 and Steedman 1977).

Tests which distinguish instances of these categories will be given in chapter 7. At this point,

the distinctions should be intuitively clear and inferrable from the examples.

An important point that has to be made about the taxonomy presented here is that it is not a taxonomy of "real world events". As was remarked before, taxonomies like these were often devised to serve as the basis for a theory of action. This resulted in classifications specifying how people act in the world (using a terminology that purposefully carries the implications of intentionality just mentioned). Our taxonomy is set up to be a classification of how people *describe* the world, rather than how the world itself is. One and the same state of affairs can be described in different ways, using expressions belonging to different categories and focussing on different aspects of the same state of affairs. Thus, the sentences in (73) could be describing one and the same "real world" state of affairs. Yet, they all belong to different aspectual categories: (a) is a culminated process indicating that that state of affairs had some duration and that it terminated at a particular time; (b) describes it as extended in time without mentioning the terminal point; (c) describes it as something which was going on at a particular point in time; and (d) just refers to the consequences associated with that state of affairs.

- (73) (a) I wrote two letters last night
(b) I wrote letters last night
(c) I was writing letters in my office
(d) I have written two letters

This also means that, when trying to decide what category an expression like *sneeze* belongs to, one doesn't have to go into the world and measure a sneeze to see whether it is atomic or extended, or to film a sneeze and play it in slow-motion to decide whether it is a structured event. Rather, one takes the expression and examines how it behaves in the language: what adverbials can it co-occur with, what changes of meaning occur when it appears with certain tense or aspect markers. These tests and the resulting classification obviously reflect the way we think about reality, but it has to be stressed that they do not pertain directly to real world entities. Hence, questions like "When I see John at work in the garden, am I looking at a *state* or at a *process*?" do not arise. Questions that do arise are whether *English expressions* like *work in the garden* or *be at work in the garden* belong to the category of process or state.

It follows from this that such an aspectual classification should not be thought of as a classification of verbs. Although Vendler did not say this explicitly, and clearly had verb phrases in his accomplishment category, it has been assumed quite often that the point of the exercise is to categorize verbs. However, as Verkuyl (1972) and following him Dowty (1972, 1979) pointed out, this is a classification of sentence-meanings rather than of verbs: subject, object, tense and temporal adverbials all play a role in determining what class an expression

belongs to. Thus (74a) seems to be basically a process, free to occur with a *for*-adverbial, and rather awkward with an *in*-adverbial. (b) seems to be a culminated process expression, going rather well with an *in*-adverbial. And (c) seems to be more like an habitual expression.

- (74) (a) John ran in the park (for a while).
 (b) Today, John ran a mile (in less than four minutes).
 (c) John runs for Scotland.

It would seem rather strange to say that *run* or a sentence containing the verb *run* is ambiguous between all these categories. It seems like a better idea to think of a Vendlerian taxonomy not as a fixed classification, but as a dynamic one where an element like *run* (or the expressions it forms when combining with other linguistic material) can move from one category to the other, provided the context is such as to support the assumptions associated with the transition in question. The classes in the taxonomy can be thought of as nodes in a network, linked by arcs indicating possible transition paths from one category to another. Labels on the arcs will stipulate what the context has to be like for the arcs to be traversed. Such a network is given in Figure 3:

The categories in Figure 3 are the same as in the previous diagram. There is still a basic distinction between states and events, but states are a somewhat more complex group now. It comprises "habitual" propositions (such as *Alice plays tiddlywinks for Scotland*), as well as propositions involving perfect and progressive auxiliaries. Note that, although for present purposes we treat progressives, habituais, perfects and "lexical" states all as states, there are important differences between them, as will emerge later.

The aspectual network describes permissible transitions from one aspectual category to another under the influence of sentential and extra-sentential context together with the associated changes in meaning and assumptions which the context must support.

There are basically two kinds of labels on the arrows. One set of labels, those between brackets, indicate characteristics of event-descriptions that cannot be read off directly from the way the aspectual network is structured - for example, the fact that an event is described as "iterated" or "in progress".

The labels on all the other arcs merely emphasize information which can also be read off from the structure of the aspectual network. Because of this, some arcs remain without labels. But even where there are labels, they are only there for ease of reference. For example, the transition from a process like *run* to a culminated process like *run a mile in less than 4 minutes*

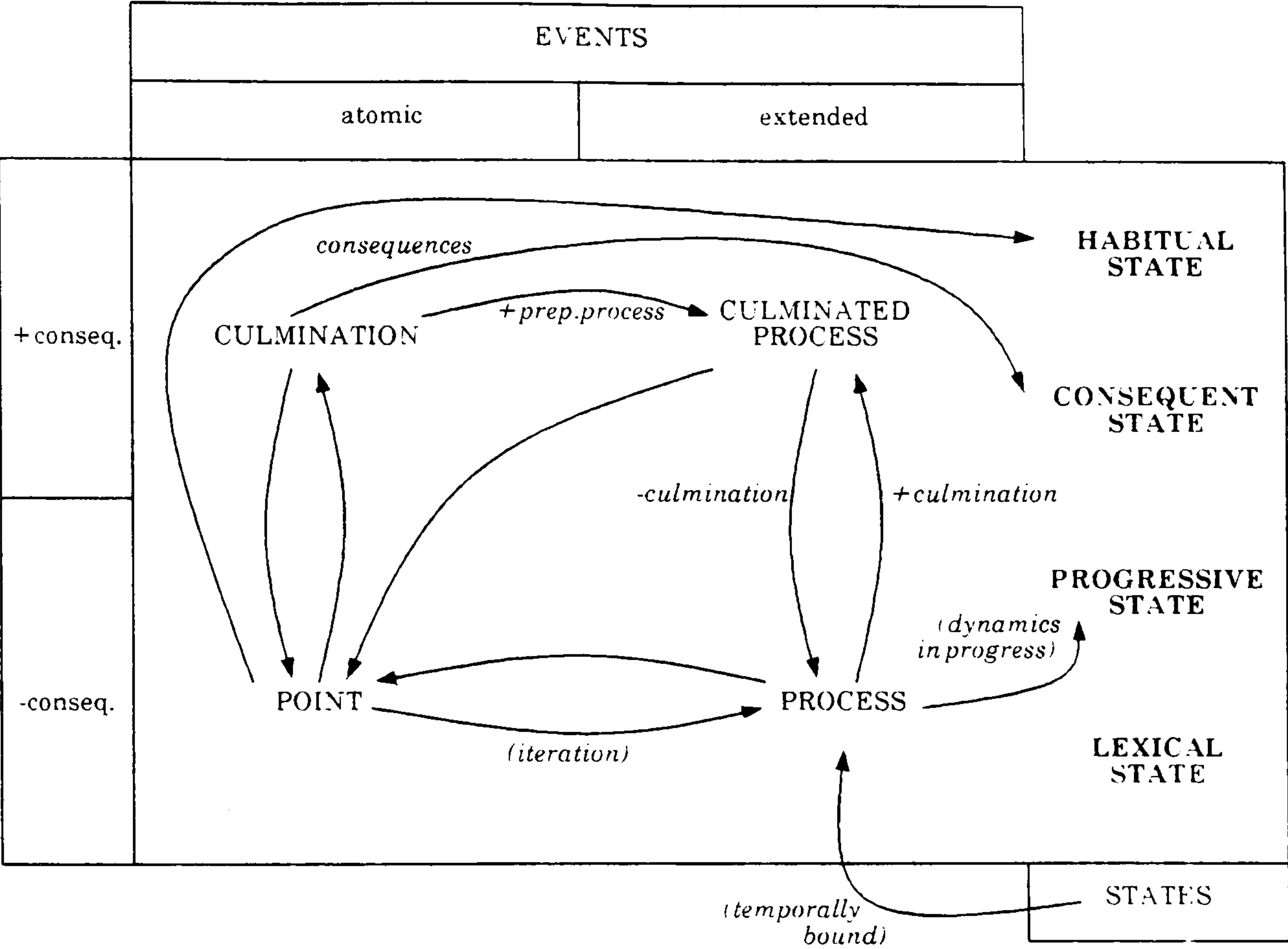


Figure 3: The Aspectual Network, specifying possible transitions between aspectual categories.

involves adding a culmination point to the original process. Once such a culmination point is added, possible consequences also come into play. All this can be read off from the network in Figure 3, since moving up from process to culminated process means moving from the category "-consequences" to the group of events that is marked "+consequences". Nevertheless, for ease of reference the transition from process to culminated process is labelled "+culmination", indicating that an extra "layer" of meaning is added to the "basic" meaning of the category the arrow starts off from. The precise nature of the culmination and the consequences are inferred on the basis of world knowledge - in this case about running in general or possibly about a particular instance of it. If the hearer's knowledge does not provide some appropriate culmination and consequences, the utterance will be judged infelicitous.

Arrows with a minus-label indicate layers of meaning that were associated with the meaning of

the category the arrow starts from, but are not described anymore by the resulting category: *read a novel* is typically a culminated process, but *he read a novel for a few minutes* indicates that the culmination point was not reached. To describe this transition, I will often use a shorthand description, saying that a certain layer of meaning is "stripped off" from the meaning complex built up so far. This should not be taken too literally: whatever layer of meaning is stripped off is not lost. In the example *he read a novel for a few minutes*, the process of reading is still described as extending towards the point where he *finished the novel*. Saying that this culmination point is "stripped off" just means that that particular part of the meaning complex is not talked about for the time being; the focus has shifted to other layers of meaning. But again, the information on the label is not indispensable and can be deduced from the overall structure of the network.

Labels without "+" or "-" indicate which part of the meaning is described by the resulting category: the arrow labelled "consequences", for example, indicates that the category it points to (viz. consequent states) refers to the consequences of the category the arrow starts from. Again, this information is merely a reminder of something which can be read off directly from the way the aspectual network is structured.

The observation made before, viz. that almost any verb can occur as almost any category, is accounted for in the network by allowing the verbal expression to move around in the network, always adding extra layers of meaning or changing focus to other layers of meaning. Thus, rather than saying that *run* is ambiguous between a process or a culminated process, it will be described as basically a process verb - occupying an interval of time and free to occur with a *for*-adverbial. But when it occurs with an object like *a mile* or with an *in*-adverbial, it changes into a culminated process by becoming associated with a conclusion or finish.

Deciding on whether a transition is feasible or which transition to take if more than one set of arcs can be traversed depends on general and specific knowledge about the world. Consider (75):

(75) John played the sonata for a few minutes.

Play is basically a process expression, which becomes associated with a particular culmination point in *play the sonata*; however, a *for*-adverbial seems to require a process rather than a culmination point to combine with, hence *play the sonata* will have to change from the culminated process node to the process node. One way of accomplishing this is by taking the arc from culminated process to process; the label indicates that this transition is felicitous if the

culmination point is stripped off. According to this account, (75) indicates that the final point of playing the sonata was not reached. What we are left with is a process of John playing the sonata, with no indication that John actually finished playing the sonata, and with the added information that this process lasted for a few minutes.

Another route through the network is possible, however. The culminated process, like any other event, can be compressed into a point - akin to Comrie's monolithic "blob" mentioned in the previous chapter. A transition to process then results in an iteration of occurrences at which John plays the sonata. Because of our knowledge about sonatas and about how long they typically last, it is not the most obvious choice to make in the case of (75). It *is*, however, the most likely interpretation for a sentence like (76):

(76) John played the sonata for about eight hours.

The culminated process expression *play the sonata* is here turned into a process of *repeatedly playing the sonata*. That process is described as lasting for about eight hours.

Since the arcs describe what the world has to be like for the transitions to be made felicitously (or, more accurately, the arcs indicate ways in which the world can be described), it is obvious that there are expressions that will resist certain changes. Consider the expression in (77), and the changes it underwent in (a) and (b):

- (77) John ran.
 (a) John ran for a few minutes (this morning).
 (b) John ran in less than four minutes (this morning).

Run is basically a process verb, which makes for easy co-occurrence with the *for*-adverbial in (77a). The (b) example describes the process of running as being associated with a particular goal, stipulating that that goal was reached in a time span of four minutes. The acceptability of a sentence like (b) depends on how easy it is for us to associate a culmination point with the process of running. General world knowledge doesn't seem to allow this possibility; particular knowledge *can* provide the necessary information, as in Dowty's example where John runs a particular distance every morning before breakfast. This also explains why the ease with which structurally similar examples can be interpreted changes from one context to the other: (78) contains the same basic expressions, but because of our knowledge of that particular domain of discourse, it is a lot easier to find an interpretation for (b) than in the previous set of examples:

- (78) (a) My program ran for a few minutes.
 (b) My program ran in less than 4 minutes (this morning).

It is clear that linguistic material, such as adverbials, auxiliaries or tenses provides important information as to what transitions the basic verbal expression undergoes. The role of these constructions in the aspectual network can be described in functional terms. Take, for example, the case where a culminated process like (79a) combines with a *for*-adverbial as in (79b).

- (79) (a) Harry delivered a sermon.
(b) Harry delivered that sermon for 4 years.

The information we want to capture is that the culminated process in (79a) has been turned into a process, thereby acquiring an iterated meaning. Yet, by associating a particular time span with that iterated process, it also gained a new conclusion or culmination point, thereby turning back into a culminated process. The information that a *for*-adverbial can only combine with a process, and that the resulting combination is a culminated process, can be represented in functional terms by stating that a *for*-adverbial coerces its input to be a process, and that it maps this process into a culminated process. The functional nature of this and some other aspectual adverbials as well as auxiliaries will be discussed in chapters 5 to 7.

In the diagram of Figure 3, a culminated process is described as a compound made up of a process which prepares for or leads up to a concluding culmination point. As was already pointed out, a process can be turned into a culminated process if it has a culmination point associated with it, as in (80):

- (80) John wrote a letter to his mother.

But one can also go the other way round, starting from the culmination node. Consider (81):

- (81) (a) The mountaineer reached the top.
(b) The mountaineer reached the top in less than 5 hours.

The expression *reach the top* belongs to the category of culminations. As will be discussed in more detail in section 5.1.2, an *in*-adverbial coerces its input to be a culminated process. According to the aspectual network, the transition from culmination to culminated process is felicitous if whatever preparatory process the context allows you to associate with the culmination of *reaching the top* is added to the basic culmination point. The *in*-adverbial describes the preparatory process associated with the culmination of *reaching the top* as taking less than 5 hours. Thus, it is clear that a culminated process consists of a process to which a culmination point is added, or of a culmination to which preparatory process is added. To clearly mark the fact that this category is such a compound, we opted for the term "culminated process"

It seems, in fact, that the meaning of all the categories in the aspectual network is associated with a complex entity consisting of a preparatory process, which can lead up to (without necessarily reaching) a culmination point, and this in turn has certain consequences attached to it.

Such a complex entity will be referred to as a "nucleus". It can be represented pictorially as follows:

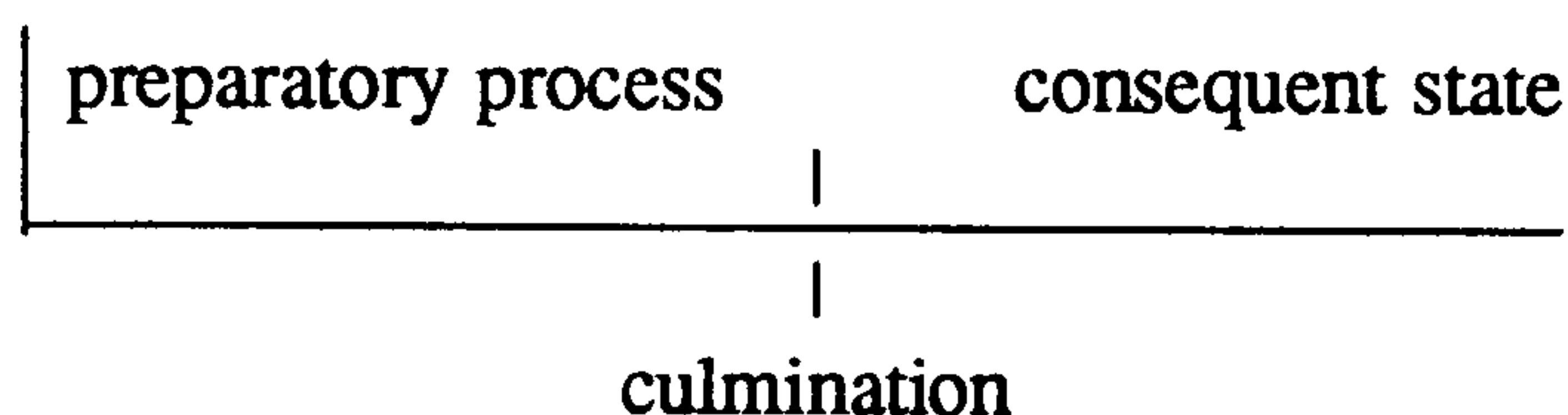
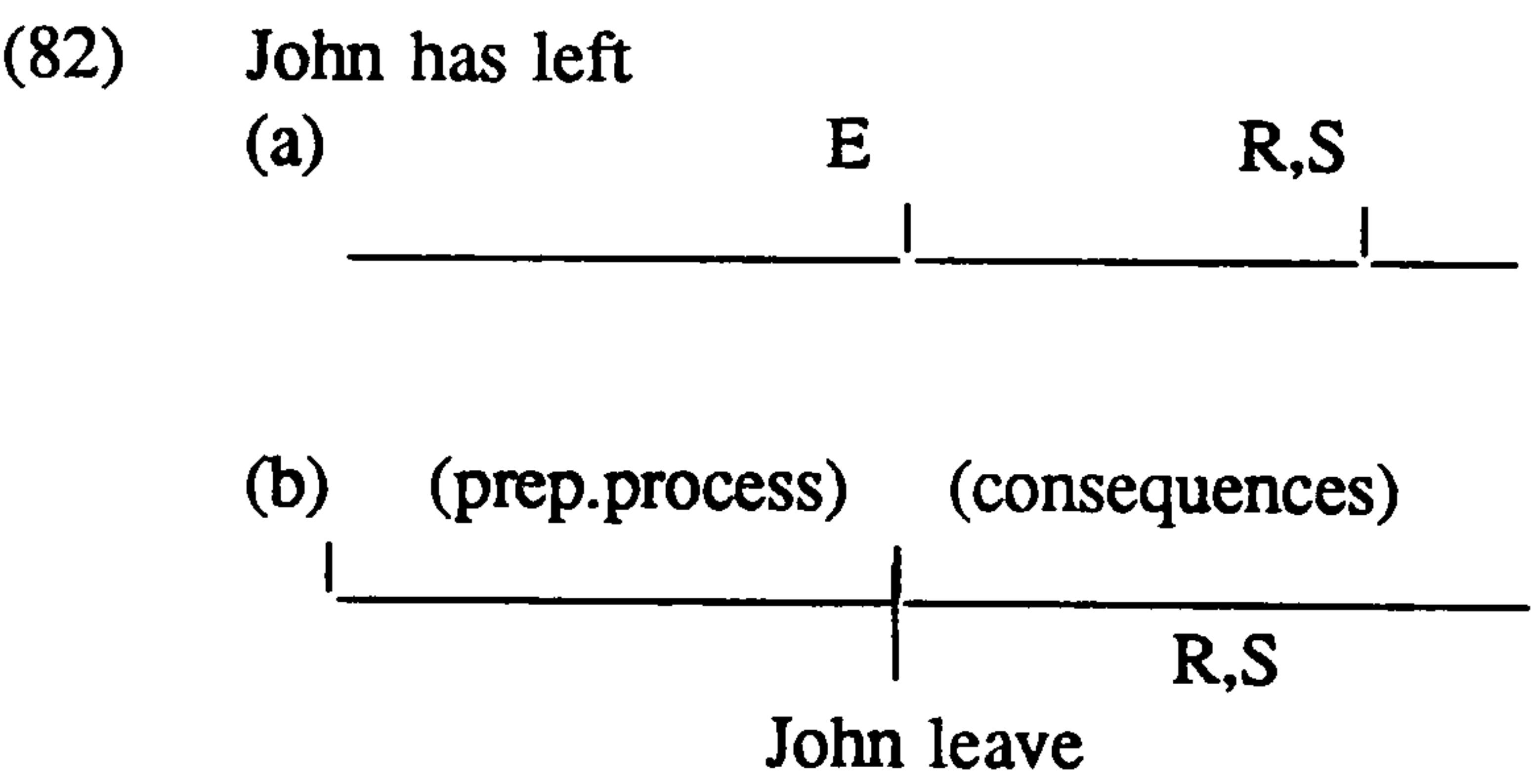


Figure 4: A nucleus.

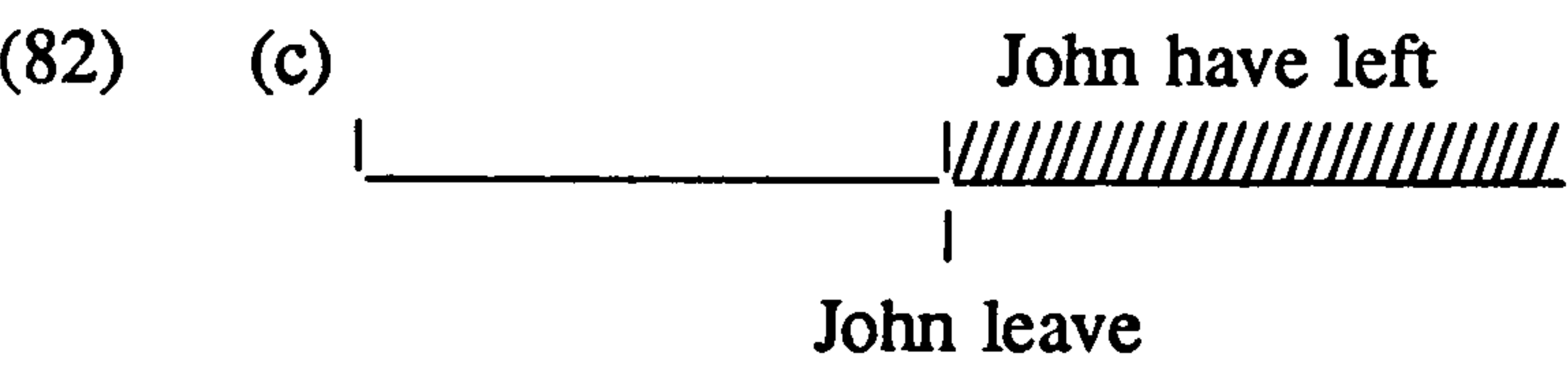
The nature of the temporal and aspectual information conveyed by a verbal expression is related to the concept of a nucleus. Depending on its position in the diagram, an expression describes different parts of the nucleus, or describes those parts from a different perspective. If the expression belongs to the culminated process category, it conjures up a complete nucleus, i.e. the point at which the event finished, the preparation leading up to this point and its consequences; a process expression it only pertains to the (preparatory) process; culmination expressions focus on the culmination point and its consequences; points only refer to the culmination without considering the consequences; and expressions belonging to the category of consequent states focus exactly that part of a nucleus.

The concept of a nucleus is what is needed to answer the question raised in earlier chapters concerning the nature of the referent to which tenses anaphorically refer. The answer is that it is not just a point or an interval on a time line, but that this more complex notion of "nucleus" plays a crucial role: the process of temporal reference involves locating the reference time at the appropriate part of the nucleus.

Thus, rather than saying that a (present) perfect is represented in Reichenbachian terms as in (82a), we can now add the further stipulation that the reference time is in fact situated in the consequences that follow the core event, as in (82b):



Since, in (b), the reference time can be placed "anywhere" in the consequences (in the sense that there is no restriction on how much time can elapse between the core event and the reference time), the whole area denoting the consequences is a possible domain for R to be located. This will be indicated by means of hatchings, as in (c). In the case of a present perfect, there will be a further restriction that reference time and speech time coincide; in the case of a past perfect, the reference time should precede the speech time.



In more general terms, then, the temporal referent of an expression is a part of a nucleus - exactly which part of the nucleus has to be determined by checking the transitions the expression underwent in the aspectual network.

4.4. Conclusion

It was claimed in chapter 1 that a proper treatment of the nature of the temporal referent and the process of temporal reference would eliminate apparent ambiguities and indeterminacies that the linguistic apparatus of tense and aspect seems to be plagued with. In chapters 5 to 7 I will attempt such an account, based on the referential structures introduced in the previous sections. This account will highlight an important characteristic of the nucleus which was left implicit so far: a nucleus is not just a temporal ordering of a preparatory process, followed by a culmination point, and that in its turn followed by some consequences, but has stronger links to keep it together. I will refer to these as *consequentiality* or *contingency* relations, of which causality and enablement are the most important ones.

Chapter 5

An analysis of temporal expressions

In this chapter, the approach outlined in the previous chapter will be developed in more detail. I will first discuss the contribution a number of adverbs and other expressions make to the temporal structure of discourse by examining their behaviour within the aspectual network diagram. In sections 2 and 3, I will go into the problem of progressive and perfect auxiliaries. I will show how the ontology proposed here allows for a unified account of both constructions. I will occasionally draw comparisons with frameworks which offer accounts of these phenomena using simpler ontologies, and show where and why these accounts fail.

5.1. The aspectual nature of some temporal expressions

5.1.1. For and until

In chapter 4, the role of adverbial expressions in facilitating transitions between aspectual categories was described in functional terms. These functions impose certain restrictions on the aspectual category an adverbial can combine with, and define the aspectual category that results.

The functional nature of a *for*-adverbial can be described as follows:

(83) *for*-adverbial: PROCESS \mapsto CULMINATED PROCESS

(83) stipulates that *for*-adverbials can only be used felicitously with a process expression, and that the resulting combination is a culminated process. Consider (84):

- (84) (a) John worked in the garden for several hours.
 (b) Harry played the piano for a while.
 (c) Mary held her breath for 2 minutes.

Expressions like *work in the garden*, *play the piano* and *hold your breath* are basically process expressions. They combine unproblematically with *for*-adverbials, which put a specific time length on the process. The result is a culminated process. The difference between the original process expression and the resulting culminated process becomes clear when both are combined with a perfect auxiliary: the processes in (85) have no consequences for the perfect to refer to; in (86), the added culmination point brings with it consequences to which the perfect auxiliary can refer:

- (85) (a) ?John has worked in the garden.
 (b) ?Harry has played the piano.
 (c) ?Mary has held her breath.
- (86) (a) John has worked in the garden for several hours.
 (b) Harry has played the piano for a while.
 (c) Mary has held her breath for 2 minutes.

When the input for the *for*-adverbial is not a process, the expression will first have to be "coerced" to be of the right type by moving it along a path through the aspectual network. Consider (87):

- (87) (a) Sue played the sonata for a few minutes.
 (b) Harry delivered that sermon for 4 years.

The expressions *play the sonata* and *deliver a sermon* belong to the culminated process category. These expressions have to be turned into processes first, before they can combine with the *for*-adverbial. As was discussed in the previous chapter, this can be done in two ways: either the culmination point is stripped off, indicating that the culmination point associated with the process is never reached; or the culminated process is described as occurring repeatedly (by choosing a transition path through the point node). World knowledge will help us decide that the first option is most plausible for (87a), the second one for (b).

This mechanism also explains the following relatively strange but acceptable examples:

- (88) (a) Mary built a house for 3 days.
 (b) Sue walked to the station for a few minutes.

The interpretation the aspectual network assigns to examples like these is the following: both sentences are said to refer to processes that have particular culmination points associated with them, although these culminations are never reached. The reason the sentences in (88) sound odd is a purely pragmatic one: there are few contexts in which one would want to express the fact that the building of a house was not finished by referring to the time period that was spent on building activity. That is why they sound better with a continuation like *and then gave up* or *but then changed her mind*. It is, however, very natural to indicate that you did not finish reading a book by drawing attention to the fact that you only spent a limited amount of time on it. Because of this, a sentence like (89) sounds quite natural:

- (89) I read a book for a few minutes (but felt rather restless and decided I had to make that phone call first).

Point expressions can be turned into processes if they are described as taking place repeatedly. They will thus get an iteration interpretation when combining with a *for*-adverbial:

- (90) John knocked on the door for a few minutes.

The combination of *for*-adverbials with culminations is somewhat more complex.

- (91) (a) John reached the top for a few hours.
(b) The train arrived for several minutes.

It is hard to find a context in which the examples in (91) mean anything at all. The reason for this lies in the way English syntax and morphology control coercion in the aspectual transition network. The transition from culmination to consequent state, for example, demands the presence of a perfect. The transition from process to progressive state may be traversed only if a progressive auxiliary is present in the sentence. For other transitions, such as the one resulting in an iterated process or an habitual statem English has no explicit markers and they can be made freely.

The transition from culminated process to process is not one that can be made freely in English, but seems to require the presence of a progressive *-ing*-form. As a result, turning the culmination in (91a) into a process by first adding a preparatory process and then stripping off the culmination point is not allowed (cf. Moens & Steedman 1987 for these constraints on the aspectual network).

There is, however, another transition path that can account for the combination of a culmination with a *for*-adverbial. The culmination can be compressed into a point, which means that the culmination is still described as an unstructured entity, but without consequences attached to it. This point can then be turned into a process, if it is described as taking place repeatedly. This reading is excluded in (91) by world knowledge which tells us that a train cannot arrive repeatedly in a time span of a few minutes. The iteration reading is, however, very plausible in examples like (92):

- (92) (a) John left the office early for several days.
(b) For months, the train arrived late.

It is important to realize the difference between these two sets of examples. The examples in (91) are anomalous because culminations are associated with a consequentially related situation - for example the situation of being at the top. This precludes an iteration of the culmination. Points do not have these consequences associated with them, resulting in a straightforward iteration reading in sentences like (90). Because of this, once the culmination has been compressed into a point, iteration *does* become a possible reading - as illustrated in (92) - since no mention is made anymore of the consequences normally associated with the culmination.

Sometimes, the combination of a *for*-adverbial with a culmination results in a totally different interpretation:

- (93) John left the room for a few minutes.

Here, the *for*-adverbial most naturally pertains to a time period *following* the culmination of *leaving the room*. This adverbial is of a different kind, however, expressing purpose rather than duration. It is merely an accident of English that the same device is used to convey these meanings. In German or French, the two constructions are clearly distinct:

- (94) (a) Pendant des années, Jean est arrivé en retard au travail.
 Jean a quitté la chambre pour quelques minutes.
 (b) Jahrelang erschien Jan zu spät zur Arbeit.
 Jan verliess für einige Minuten das Zimmer.

Before states can combine with *for*-adverbials they have to be turned into processes. This is a rather straightforward transition: states are typically thought of as extending in time, and turning them into processes only adds a notion of temporal boundary to the extended event.

- (95) John was ill for a few days.
 He believed in Santa Claus for quite a number of years.

There are some states which express relatively permanent, inalienable properties, and which are hard to think of as having temporal bounds. Quite a lot of context is needed before they can occur with *for*-adverbials:

- (96) The cepteryx was a mammal for several centuries.
 I was rather tall for a number of years.

The aspectual mapping used to explain the behaviour of *for*-adverbials can also be used to explain the role of a connective like *until*: it coerces its input category to be of the process type. The resulting expression is a culminated process. This results in readings very similar to the ones that were just discussed for *for*-adverbials. Consider the examples in (97):

- (97) (a) John worked in the garden until sunset.
 (b) Harry played the sonata until five.
 (c) John arrived late until his boss told him off.
 (d) Sue knocked on the door until her knuckles were bleeding.

Combination with a process expression (97a) is unproblematic. The *until* clause specifies the time at which the process culminated. When combined with a culminated process expression (as in b), *until* allows two interpretations: one where the final point is not reached, one where the event occurred repeatedly. Combination with culminations brings up the same problems that were discussed before for *for*-adverbials: there is no straightforward process interpretation for culminations, unless context makes an iterative reading plausible. Such an iterative reading

is also the most straightforward interpretation when *until* is combined with a point expression (as illustrated in 97d). Finally, combination with states poses the same problems as with *for*-adverbials: where states are concerned that express inalienable properties, combination with *until* will be hard:

- (98) I was quite ill until I took the anthrophax.
 ?I was quite tall until I met Harry.

5.1.2. In-adverbials

Not all adverbials denoting a time span fulfill the same function as *for*-adverbials. *In*-adverbials are essentially different in that they require their input to be of the culminated process type. The result of the combination is still a culminated process.

- (99) *In*-adverbial: CULMINATED PROCESS |--> CULMINATED PROCESS

Consider (100):

- (100) John built a house in less than a year.

The expression *build a house* belongs to the culminated process category. Therefore, no extra changes are needed before it can combine with the *in*-adverbial; the result is still a culminated process.

Culminations can combine with *in*-adverbials provided they are changed into a culminated process expression first. This transition is felicitous if one adds a preparatory process to the referent of the expression. The *in*-adverbial then indicates the length of this preparatory process:

- (101) (a) The mountaineer reached the top in less than 3 hours.
 (b) The train arrived in 5 minutes.

The fact that certain culminations *cannot* occur with *in*-adverbials supports this analysis. Consider the following example:

- (102) *John accidentally spilled his coffee in less than 5 minutes.

A verb like *spill* expresses an involuntary act, which makes it hard to think of a context where a preparatory process can be associated with it. If the context is such that one *can* think of such a preparatory process, for example in a situation where John often spills coffee or falls in man-holes all the time, sentences like (103) can be used felicitously.

- (103) (a) In less than 3 minutes, John fell down a man-hole.
 (b) It took John only 2 minutes to spill a coffee on his brand-new sweater.

The accidents in (103) are still involuntary, and as such have no preparatory process associated with them. They are *described*, however, as if they *do* constitute purposeful behaviour. The

in-adverbial pertains to the time period John needed to achieve this "goal".

When the expression combining with the *in*-adverbial is inherently a process (e.g. *run*), a transition path has to be found to the culminated process node first. One possibility is to make a transition to the culminated process category, which - according to the aspectual network - is successful if the context allows one to associate a culmination point with the process:

(104) My program ran in less than four minutes this morning.

Alternatively, the process (in this case: *running*) can be made into an atomic point, and then into a culmination. Before this culmination can be combined with the *in*-adverbial, it has to acquire a preparatory process of its own which we can think of as *preparing to run*. In this reading, the adverbial in (104) indicates how long the preparatory period leading up to the start of the process lasted.

Statives can be combined with an *in*-adverbial provided that the transition from situation to process can be made felicitously. The problems involved with this were discussed in the previous section. Once the transition has been made, the possible interpretations from that point on are the same as those allowed by processes proper. Because of this, the ambiguity discussed with respect to (104) also shows up in some of the examples in (105):

- (105) (a) In less than ten minutes, John understood the ins-and-outs
of the whole problem.
(b) John slept in an hour
(c) In less than a day, Bea knew the answer.

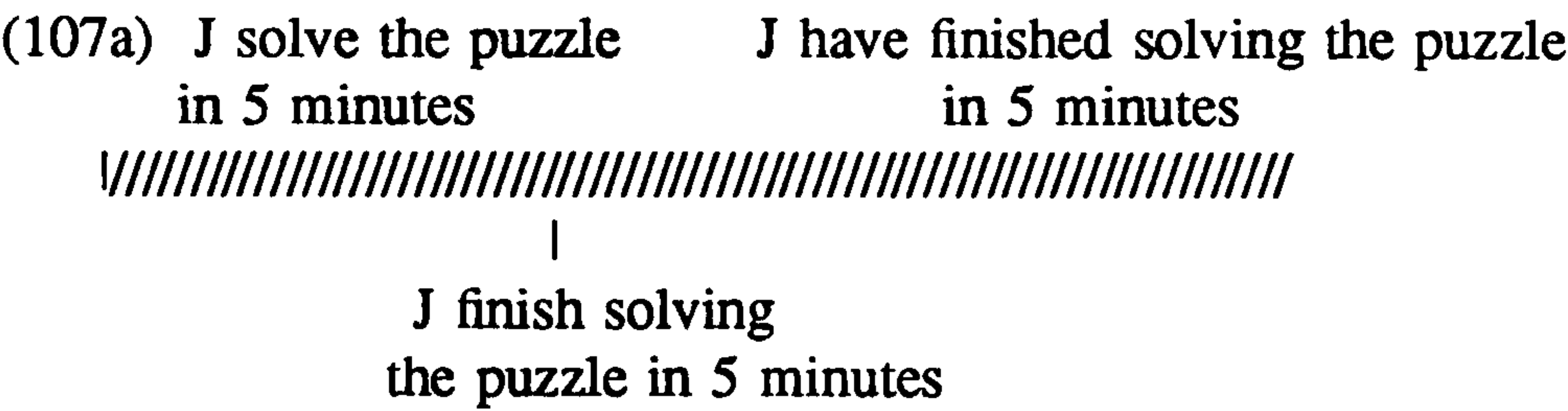
Dowty (1979: 346) points out a similar ambiguity in constructions with progressives:

(106) John was solving the puzzle in 5 minutes.

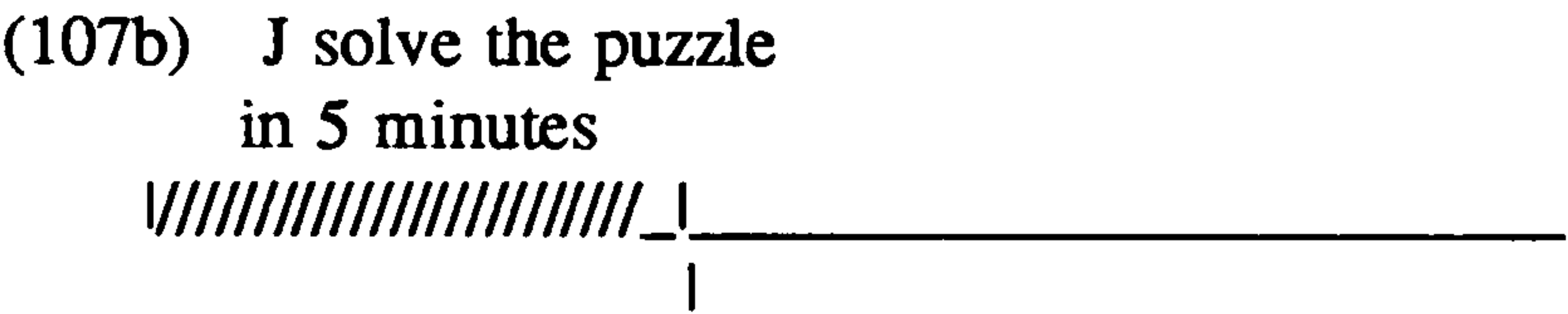
This sentence either has an inchoative interpretation, describing a 5 minute period leading up to the point where John starts solving the puzzle; or it describes John as being engaged in a process of solving a certain puzzle in 5 minutes. Dowty accounts for the two readings by giving the aspectual adverbial scope over the progressive operator in the case of the inchoative reading, and vice versa for the other interpretation. The account for this ambiguity in terms of network transitions is very similar to Dowty's scopal account: it depends on whether the functional transition required by the *in*-adverbial is executed before or after the transition needed for the progressive.

The expression *solve the puzzle* is typically a culminated process expression, allowing for straightforward combination with the *in*-adverbial. The resulting expression is still a culminated process, and has associated with it a complete nucleus which can be represented as in

(107a):

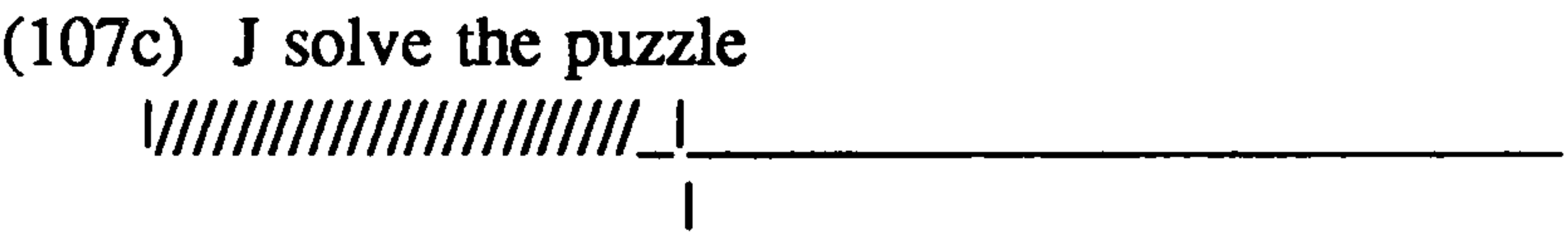


The transition from culminated process to process strips off the culmination point and the consequences, as in (b):



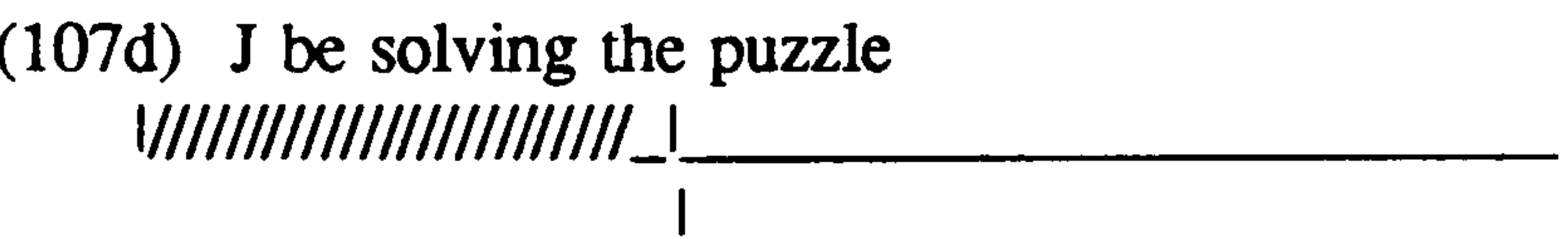
The progressive describes this process as ongoing at the time of reference, resulting in the interpretation of (106) that John is engaged in the process of solving a particular puzzle in 5 minutes.

But the culminated process expression *solve the puzzle* can also be coerced into a process first. This process will have the following nucleus associated with it:



The progressive then describes the process of solving the puzzle as ongoing at the time of reference, without implying that John actually solved the puzzle.

Combination with the *in*-adverbial is possible only if this state is turned into a culminated process first. First, the progressive, like any other state, can be turned into a process. The result is a process which is different from the one depicted in (107c):



To turn this process into a culminated process, the most obvious route through the aspectual network is the one that turns the process into a point and then into a culmination. The addition, finally, of a preparatory process allows for the combination with the *in*-adverbial which describes the length of time leading up to the point where John was engaged in the process of solving the puzzle.

One other aspectual expression whose behaviour can be described in the same terms as that of

the *in*-adverbial is the expression *it took him...*, as in (108):

- (108) (a) It took him 3 hours to reach the top.
 (b) It took Sally several minutes to arrive on the platform.

5.1.3. Negation

The influence of negation on the aspectual character of sentences, and thus on the temporal structure of the discourse these sentences appear in, can be represented as follows:

- (109) *negation*: STATE \mapsto STATE
 EVENT \mapsto PROCESS

Negation can combine with expressions of any aspectual type. If the input expression is a state, the resulting negation is also a state:

- (110) John isn't here.
 Sue is not working in the garden.

Negated events behave like process expressions, free to co-occur with a *for*-adverbial.

- (111) John didn't play the sonata (for several days).
 For hours, nobody arrived.

The role of negation in discourse is far more complex than what is said here about the aspectual nature of negative clauses. In chapter 7, I will offer some further evidence as to why (110) should be classified as a stative expression and (111) as a process. This brief sketch is merely intended to note an interesting interaction between some of the expressions dealt with so far. Consider the following example:

- (112) Jerry did not work until 5 p.m.

As was discussed before, *work*, which is inherently a process expression, forms a culminated process expression after combination with *until*. The negative particle indicates that it is not the case that this culminated process took place, stripping off the culmination point. Under this interpretation, the sentence means that John did work, but not all the way up to 5 p.m. Alternatively, *work* combines with the negative to form the process expression *not work*. Combination with *until* is straightforward, since this connective wants its input to be of the process variety. This yields the interpretation that the process of John not working lasted until 5 p.m. There may be an implicature that he started immediately after 5 p.m., but that is not entailed by (112).

5.2. Progressives and the Imperfective Paradox

In this section I will look more closely at the progressive and its role in the general framework outlined so far. I will first explain why progressives are classified as statives in the network diagram. De Vuyst (1983) and Comrie (1976) will be discussed as representative of opponents to such a classification. I will then discuss what the temporal referent of a progressive looks like.

Next, I will concentrate on one notorious problem concerning the semantics of the progressive, viz. the imperfective paradox (cf. section 3.2). I will show that the theory presented here provides a satisfactory account of the phenomena involved, and I will argue that accounts based on simpler ontologies fail to be descriptively adequate, or have to add *ad hoc* machinery to make the account work.

5.2.1. Progressive states

In the proposed network of aspectual classification progressives are classified as states. Since this is a characterization of the progressive not often found in the literature (Steedman 1977, Vlach 1981a, Bach 1981 and Dowty 1986 are the most important exceptions) some defence may be needed.

Most treatises on aspect and aspectual characterization propose to determine whether an expression is stative by testing whether that expression combines with the progressive or not. If it does not, it can be classified as stative. Although this test should not be taken at face value (cf. section 7.2), it does support our characterization of the progressive as stative:

- (113) (a) *John is being walking
(b) *Pepe is being eating chilis

Moreover, the main verb in the progressive construction is *to be*, and most constructions with *to be* are stative. Finally, as Vlach (1981), following Anderson (1973), points out, most progressives have locative paraphrases, and locatives are clearly stative expressions:

- (114) (a) John is working
(b) John is at work

Vlach (1981), Anderson (1973) and Bolinger (1971) contain many other cross-linguistic and historical arguments that favour a characterization of the progressive as a stative expression. In chapter 7, I will propose a general test to distinguish states from event descriptions.

A recent attack of the view that progressives should be classified as stative can be found in de

Vuyst (1983). He defends his claims on the following grounds. First of all, he argues that there is no obvious relation between state descriptions on the one hand and non-progressive process and culminated process descriptions on the other. As a result, the classification of a progressive sentence as a stative obscures the way it relates to its non-progressive counterpart (1983: 172). This argument certainly holds true for many existing theories. But the account offered here is set up in such a way that descriptions of these relations *are* explicit and clear. I will therefore consider de Vuyst's argument not as an objection against the framework defended here, but as a prerequisite it has to live up to.

Secondly, de Vuyst claims that progressives typically express movement, whereas states do not. He formulates this criterion in terms of minimal versus non-minimal situations: any sub-part of a state, even a minimal one, can still be described in terms of that state; progressives, on the other hand, cannot be described that way (1983: 173). The argument roughly goes as follows. Imagine a film of a man walking up the stairs. If one looks at a single frame of that film, it is impossible to say *He is climbing the stairs*, for the man might be going down or standing still. In other words, such a static frame can only be described by using a stative expression, like *He is on the stairs*. This, it is argued, clearly distinguishes processes (like *He is climbing the stairs*) from statives (like *He is on the stairs* - cf. Dowty 1979: 168 for a similar argument).

However, this argument takes the idea of movement, as expressed by a progressive, to be a real world property instead of a way to *describe* certain real world events. Once this difference is acknowledged, a great number of counter examples readily spring to mind. When looking at a picture of John lying in bed, for example, one can assert *John is lying in bed*; in this case, then, this progressive would have to be categorized as stative. Also according to de Vuyst's argument, one frame of a flying bird would not be sufficient to say *This bird is flying*, for it might be falling, or just hanging still. But this also means that one frame does not allow one to say *This is a bird in full flight*, although the latter expression is clearly stative.

Moreover, world knowledge will inevitably interfere with "what one can say" about a frozen film frame. Anyone looking at one frame of a baby being born will decide *This baby is being born*, without even considering whether the baby was perhaps on its way in, or just got stuck there some time ago and has been there ever since. Again, this progressive would have to be classified as stative.

De Vuyst's arguments are more fine-grained than this sketchy outline suggests. He also introduces conditions on the felicitous use of expressions from certain aspectual categories in the form of a set of linguistic tests, designed to distinguish between states, activities and the other categories he works with. These tests are formulated in terms of accessibility conditions. One of them involves checking whether a punctual temporal adverbial can "get inside" the extended situation expressed by a stative expression (115a) or an activity (b):

- (115) (a) Ron was very happy at 6 o'clock.
(b) John ate at 6 o'clock.

In (115a), the punctual expression "at 6 o'clock" falls somewhere within Ron's state of being happy; in (b), it marks the *start* of John's dinner. From tests like these, de Vuyst concludes that states are accessible whereas activities are not. The argument takes a strange turn, however, when de Vuyst claims that progressives are accessible activities (1983: 173). This means that, whereas he sees a difference between states on the one hand and activities and progressives on the other in terms of a real world property, viz. movement, he also claims that from a linguistic point of view and on the basis of linguistic tests, progressives can be said to possess the one property that is characteristic of states, viz. accessibility. Since I take any classification in terms of states and other categories to be a classification of linguistic material rather than of real world events, it is clear that de Vuyst's arguments support the claim defended here, viz. that progressives behave as statives.

The reasoning underlying Comrie's rule (1976: 49) that processes can be distinguished from states in that the former require an input of energy whereas the latter do not, exhibits a similar confusion between linguistic properties and real world properties. According to this rule, *John is working in the garden* would be a process, because of the energy needed to keep the activity going; *John is lying on his bed* would be a stative progressive, because no energy input is needed; yet, the expression *John is at work in the garden*, which is generally considered to be stative, would be an activity since it requires energy to keep going.

The inappropriateness of the energy criterion becomes clearest when it is taken to an extreme: does *falling* as in (116) need an input of energy?

- (116) The apple is falling.

As the apple does not seem to require any input of energy, this progressive would, in Comrie's view, be stative. Comrie's argument could be salvaged by the claim that there *is* input of energy, coming from the earth's gravitation. But this could then be countered by the observation that, if through some trick the whole earth, except for the falling apple, were to disappear,

the apple would keep on falling (or at least moving) through space at exactly the speed it had at the moment the earth disappeared. The absurdity of this kind of argument illustrates that this approach definitely does not provide a consistent basis for the categorization of expressions in terms of their aspectual class.

The ultimate aim of our attempts to set up a network of aspectual categories and the changes they can undergo, is to provide a conceptual basis that can be used to account for the way events are temporally related to one another in discourse. Thus, tests proposed to distinguish between the basic categories of verbs and our descriptions of the changes certain contexts make in the aspectual characterization of a sentence, should always be seen in the light of the contribution they make to the event representation the hearer constructs when processing temporally referring expressions. The main argument to support our claim that progressives should be classified as statives also has to be seen in this light.

Take, for example, the way a stative expression like *Max was in the garden* behaves when it is followed by a *when*-clause.

(117) Max was in the garden when Selina came in.

The stative main clause clearly refers to a period starting somewhere before and continuing at least until the time of Selina's arrival, about which it is asserted that Max was in the garden. When the stative expression is, however, substituted by a culmination, culminated process or process main clause, the temporal relation between the clauses changes, as the following examples show:

- (118) (a) Max died when Selina came in.
 (b) Max told a joke when Selina came in.
 (c) Max ran when Selina came in.

These sentences assert that Max died, or *started* to tell a joke or *started* to run at the very moment or just after Selina arrived. In other words, the achievements, accomplishments and activities describe the state of affairs in a way that is clearly different from the way statives do.

When we compare this to the examples in (119), it turns out that progressives refer in much the same way as statives do.

- (119) (a) Max was dying when Selina came in.
 (b) Max was telling a joke when Selina came in.
 (c) Max was running when Selina came in.

These sentences assert that Max was dying (or telling a joke or running) for some time preceding and leading up to (and probably extending beyond) the moment when Selina came in.

In short, although there are several good reasons to classify progressives as statives, our main argument is based on the way in which statives refer to temporal events. In this respect, they are convincingly stative. I will return to this point in chapter 7.

5.2.2. A functional account

As was noted in the previous chapter, the functional nature of the progressive can be represented as follows:

(120) Progressive: PROCESS \mapsto PROGRESSIVE STATE

This indicates that a progressive auxiliary can only combine with a process expression. The result is a progressive state, which describes the process as being in progress. Vlach (1981) offers a similar view. The drawback of his approach is that, for different classes of expressions, he has to state how their interpretation changes when the progressive operator is applied to them. These changes can be read off directly from the aspectual network presented here. An expression like *work in the garden*, for example, is basically a process description. This means that no further movement through the network is needed to combine it with a progressive. The resulting expression describes the process as on-going:

(121) John is working in the garden.

A culminated process (like *write a novel*) can only combine with a progressive if a route is found from culminated process to process first. The most obvious one is labelled "-culmination", involving the "stripping off" of the culmination point from the referent of the expression. What we are left with is a process (that of *writing*), with its associated culmination point, but without indication as to whether this culmination point was actually reached. The progressive then describes this process as in progress. Because of the transition from culminated process to process before the combination with the progressive, a sentence like (122) does not imply that John ever finished writing that novel.

(122) John was writing a novel.

The transitions a culmination has to undergo before it can combine with a progressive are somewhat more complex. Starting off with an expression like *reach the top*, we have to find a path to the process node. The most straightforward one goes via culminated process, bringing into focus whatever preparatory process world knowledge allows one to associate with the culmination. Moving down, from culminated process to process, the culmination point is "stripped off". The progressive then describes that preparatory process as ongoing:

(123) John is reaching the top.

Points (like *tap*) have a simple transition path to processes, indicating an iteration of the point event. The resulting progressive expression describes that iterated process as ongoing:

(124) John was tapping on the door.

Sentence (124) could be assigned a second interpretation, one where John was about to tap on the door. This interpretation can be derived by taking a more complex route of transitions: from point, over culmination and culminated process to process. The end result of these transitions is that *tap* is thought of as a culmination (with certain consequences), a period of preparation is added and finally the culmination is stripped off. What is left is whatever preparation one can think of for an event like tapping on the door. That this is hard to do explains why that second reading does not readily spring to mind in the case of (124).

The compatibility of progressive auxiliaries and stative verbs is a notorious problem. According to the aspectual network and the functional nature of the progressive, for a stative verb to be combined with a progressive auxiliary it has to be turned into a process first. As was discussed in the previous section, this only involves thinking of the state as being restricted in time, which is relatively easy to do. This process is then turned into a progressive state. This transition is not an unlabelled one; there are prerequisites on it, which I have ignored in the exposition so far. To see what these restrictions amount to, it is worth looking in some more detail at the cases where a state *can* felicitously combine with a progressive.

Sag (1973) provides a helpful description of the correlation between stative verbs and the type of progressive construction they can occur in. Some of his results can be found in (125). The different progressive constructions are listed from (A) to (G). These allow increasingly more stative expressions, a selection of which are numbered from (i) to (ix). Sag's claim is that once a stative verb can occur in a certain progressive construction (e.g. in the perfect progressive, D) it will also occur felicitously in all following constructions. i.e. raised subject constructions (E), *more & more* constructions (F) and reduced relative clauses (G). For example, stative expression (i) is acceptable with a progressive auxiliary as a futurate (construction A), from which it can be deduced that it can occur in all other progressive constructions. The construction *be + certain adjectives* - expression (ix) - cannot occur in any, or at best one, of the progressive constructions (viz. G). From these data, Sag concludes to a hierarchy from less to more stative verbs, ordered here from (i) to (ix). These constructions are (i) *hear, see* (ii) *hear + ing-form*, (iii) *expect, sound*, (iv) *want, owe*, (v) *love*, (vi) *know*, (vii) *resemble*, (viii) *have*,

guess, and (ix) *be stubborn, be a communist*,....

(125)

(A) futurate progressive

- i. Tomorrow, I'm hearing what our opponents have to say.
- ii. *Tomorrow, we're hearing Jon misquote Russell.
- v. *Tomorrow, Mary is loving her baby.
- ix. *Next week, John is being unaware of the problem.

(B) process progressive

- i. Right now, I'm hearing what our opponents have to say.
- ii. At the moment, we're hearing John misquote Russell.
- iii. At the moment, Harry is expecting to be selected.
- iv. ?At the moment, the kids are wanting us to bring them toys.
- vii. *The baby's resembling his father right now.

(C) habitual progressive

- i. Nowadays, I'm hearing what our opponents have to say.
- iii. These days, John is expecting Barry to be nominated.
- iv. Nowadays, the kids are wanting us to bring them toys.
- vi. *Nowadays, Judy is knowing the answer.

(D) perfect progressive

- ii. I've been hearing Jon misquoting Russell for years now.
- v. ?Mary's been loving her baby for some time now.
- viii. *John's been having a car for years.
- ix. *Max is having been stubborn for long enough now.

(E) raised subject constructions

- iii. The police seem to be expecting a huge crowd.
- iv. Little Linda seems to be wanting something.
- vi. ?Janet seems to be knowing quite a lot about politics.
- ix. *Harry seems to be being a communist.

(F) "more & more" constructions

- iv. The kids are wanting more and more toys.
- vii. The baby is resembling his father more and more.
- ix. *Wally is being more and more an idiot.

(G) reduced relative clauses

- vii. All children resembling Pipi Longstocking will get a price.
- ix. *Anyone being a communist will be shot.
- ix. Anyone being stubborn will have his toys taken away.

I do not present these data because I agree with Sag's intuitions or his predictions. The construction *be + adjective*, for example, can in certain cases occur in the (B)-construction as a process progressive:

(126) John is being very stubborn at the moment.

This would mean that construction (ix) should appear much higher on the list.

The important point is that these data give some idea of what it involves to think of states as processes before turning them into progressive states. Agentivity seems to play a role: it seems almost impossible to find any context where *be unaware* can be used in a progressive. On the other hand, *resemble* is equally out of the agent's control, yet it does allow a progressive. Its use seems to be pretty much restricted to the *more & more* construction - i.e. to describe a process that has certain phases ascribed to it.

This seems to be a general characteristic of progressives. Lyons remarks that the English progressive does not just express durativity (like the Slavonic imperfective and the Romance imperfect), but also "dynamism" or "non-homogeneity of temporal contour" (Lyons 1982: 116). A state is usually characterized by the fact that every segment of a state is like any other segment of that state, and this complete homogeneity is obviously carried over when the state is turned into a process. A progressive, however, needs a process with some heterogeneity, or with stages that succeed each other. Possibilities of a progressive auxiliary with a stative verb seem to be determined by the ease with which one can think of the state as having successive stages: for *resemble* this can be done relatively easily, for *be unaware* this seems almost impossible. This is what is meant by the label "dynamics in progress" in the aspectual network.

It is the dynamic meaning component of the progressive which accounts for some of the non-basic meanings often associated with the use of the progressive. One of these is the notion of "behavioural description", typically found in examples like (127):

(127) John is knowing more and more about mathematics.

These sentences have an element of "iterated demonstration" - (127) seems to suggest that John is repeatedly showing that his expertise in mathematics is increasing, perhaps by repeatedly producing correct answers in class. Once the context allows this notion of "iterated demonstration" or inherent structure to be associated with the original state, interpretation of the progressive does not pose any problems any more.

The fact that a bounded event is described as being in progress suggests that it will not be in progress for ever. This is what is meant by the notion of "limited duration" or "temporariness" which has often been ascribed to the progressive (e.g. Comrie 1976: 38). However, the use of this notion, viz. that the progressive denotes limited duration, without a study of the mechanism that underlies this sense of the progressive, has led to a lot of confusing discussion in the literature. In Leech (1971), e.g., the progressive is said to describe processes with limited

duration (1971: 17-18; 128a) as well as the ceaseless persistence of a process (1971: 29; 128b):

- (128) (a) The engine is working perfectly.
(b) The earth is turning on its axis.

What Leech seems to ignore is that "temporariness" is a way of describing a real world event. Although we know that the earth's motion around its axis is ceaseless for as long as there will be an earth, (128b) nevertheless describes it as an ongoing process, with the connotation of limitedness automatically attached to it. A clear example of the degree to which this notion of limited duration is linked to our way of perceiving and describing states of affairs is given by Dowty (1979: 175):

- (129) When you enter the park, there will be a statue standing
on your right and a small lake will be lying directly in
front of you.

In (129), the position of the moving observer is taken as a "fixed" point of orientation; stationary objects thus become temporary relative to the point of orientation.

The account given here provides no restriction to block progressives of perfects or progressives of progressives. In fact, it sometimes does make semantic sense to have constructions like these. Progressives of perfects would indicate that certain consequences of an event are presently ongoing. Without wanting to push the parallels too far, ongoing consequences are what is denoted by the nominalized ing-forms in (130):

- (130) Having waited for several hours, I decided to go home.
Having been denied a right to reply, I sued them.

And, in fact, Gazdar e.a. (1982) claim that progressives of perfects *do* occur in finite clauses as well:

- (131) John began having already left for lunch by the time Mary arrived
for work each day.

If (131) is acceptable, the aspectual network will predict what its semantics is; if it is unacceptable, it will have to be blocked on syntactic grounds.

The same is true for progressives of progressives. Halliday (1980) notes some examples of this construction, taken from fast dialogue:

- (132) (a) We decided not to come to the party, it being raining cats and dogs.
(b) - Is the deadline a rigid one? Can you ever get an extension?
- You can get an extension, on the grounds of being teaching.

The simpler construction *on the grounds that you are teaching* misses the point that it is at this particular point in time that the teaching is going on; it makes good semantic sense in (b) to use the progressive of the progressive instead. If one wants to rule it out as ungrammatical, a

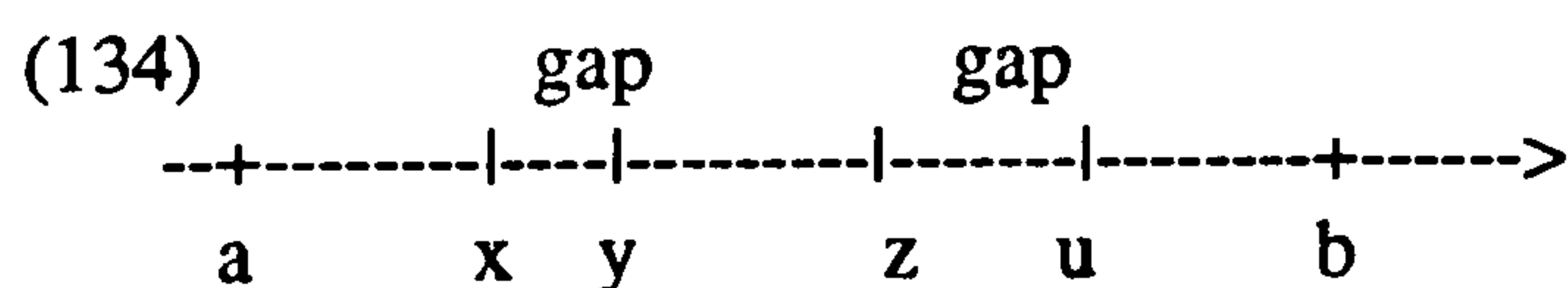
syntactic rule will be needed.

Similarly, habitual states can occur with a progressive auxiliary, as in these examples noted by Vlach (1981b: 75):

- (133) (a) Max was running a mile in less than 4 minutes
(until he bought a new watch).
(b) I was walking to work last winter.

Sentences such as these are not progressives of culminated process expressions, but of habitual states: a culminated process, like any other event, can be turned into an habitual state without the addition of any overt habituality marker. The resulting habitual state, like most states, can be turned into a process, which can then combine with the progressive auxiliary. The result is the description of a habit in progress. At no point during these many transitions is the culmination "stripped off".

What, then, does the temporal referent of a progressive look like? It is often claimed that the referent of a progressive only consists of those parts where the event is actually going on. Take, for example, the event of *reading a book*, extending in time from a to b, with gaps as indicated in (134):



According to Gabbay & Moravcsik's algebra of events (1980), for example, the progressive would pick out the intervals (a,x), (y,z) and (u,b). As a result, a sentence like (135)

- (135) Rosanne was reading a book when the phone rang

would come out as true if the reference event set up in the *when*-clause (the moment the phone starts to ring) occurs somewhere within the aforementioned sub-intervals during which Rosanne is actually reading a book.

This does not, however, seem to be accurate enough. Consider the following example:

- (136) John was building a house when his father died.

For this sentence to be true, the reference event in the *when*-clause need not necessarily occur in a period in which John was actually engaged in the activity of building a house. This seems to indicate that the period referred to by a progressive can consist of the *whole* interval (a,b), including the many gaps.

On the basis of this observation, some researchers have decided to distinguish two categories

of progressives: one which is true at any time between the starting point and the end point (the "broad progressive", Galton 1984), and one which only selects intervals of actual activity (the "narrow progressive"). This distinction is made because the two types of progressive are claimed to have different entailments: *John is reading a book* entails *John is reading* in the case of the narrow progressive but not in the case of the broad use of the progressive (Galton 1984:89-143).

This argument seems to be misguided on two counts. First, the so-called narrow and broad progressive do *not* (necessarily) have different entailments. At this moment, for example, I am writing this section of my thesis; the progressive is used in its narrow sense. This entails, obviously, that I am writing. If I now were to walk out of the office and some-one asked me if I was doing anything interesting, I could still say *I am writing* - which is the same entailment but from a progressive used in its broad sense. So both uses of the progressive seem to allow the same inferences.

Secondly, examples with verbs like *read*, *write* and *eat* are misleading since these verbs do not *have* to be used transitively. This facilitates constructions like *He's reading*, *I'm eating*, etc. It is true that (136) can be uttered when John is not actually engaged in building activity at the moment of his father's death (which makes it a "broad" progressive); and the inference to (136') is certainly odd:

(136) John was building a house when his father died.

(136') John was building when his father died

The oddity of (136'), however, does not prove that we are dealing with a broad progressive, but rather that (136) involves a necessarily transitive verb. Equally, from (137), taken in its narrow sense, one cannot infer (137'):

(137) John was making a chair (when I came in).

(137') John was making (when I came in).

It seems that whether the referent of a progressive has gaps depends on our world knowledge about the type of process that can be associated with the nucleus. The apparently different temporal referent set up by an event such as *reading a book* as opposed to *building a house* seems to be determined by the type of preparatory process we can think of as leading to the respective culmination points. The preparation leading to the completion of a house allows one to accept temporary lulls in that preparation which can still be described as house-building. Reading a book does not have this kind of preparatory process; putting aside the book in most cases means one stops reading the book, although this is not necessarily the case. Consider:

- (138) (a) Was Sue reading a book when she met George ?
 (b) Was Sue reading *Finnegans Wake* when she met George ?

Question (138a) asks whether Sue was actually engaged in the activity of reading when she met George. This need not be the case in (138b). The preparatory process we associate with finishing *Finnegans Wake* (as with completing a house) allows us to think of the activity as having gaps.

5.2.3. The imperfective paradox

No treatment of the progressive can be called satisfactory, unless it also provides an account of what is now generally called the imperfective paradox (Dowty 1979: 133-154): this concerns the question of how the meaning of a sentence with a progressive is related to the meaning of the corresponding non-progressive sentence. The problem of the imperfective paradox hinges on the fact that *John was drawing a circle* does not imply that *John drew a circle* or that *John has drawn a circle*. The fact that John is engaged in the activity of bringing a circle into existence does not mean that he necessarily *does* bring that circle into existence. Yet, *John was drawing a circle* is different from *John was drawing a triangle*, so apparently there is something, not a circle yet clearly distinguishable from a triangle, that is being drawn.

The exact meaning relation between progressive and non-progressive sentences cannot be isolated from the aspectual characterization of the sentences concerned - a fact that has been recognized since the earliest work on verb classification (e.g. Kenny 1963): only progressives of culminations and culminated process expressions exhibit this puzzling behaviour. From a progressive process expression (like *John was working in the garden*) one *can* infer that he worked in the garden.

Various people have tried to deny the existence of this paradox. Taylor (1977: 210), for example, claims that if one is writing a letter and is interrupted at a time *t*, then it is not really true at *t* that one was writing a letter. Rather, at *t* one was doing something which *would have been* the writing of a letter if it had not been for the interruption. This, however, does not account for English usage: sentences such as the following can be uttered truthfully:

- (139) When he died, he was writing his 9th symphony.
 (140) He was crossing the street when he got run over by a truck.

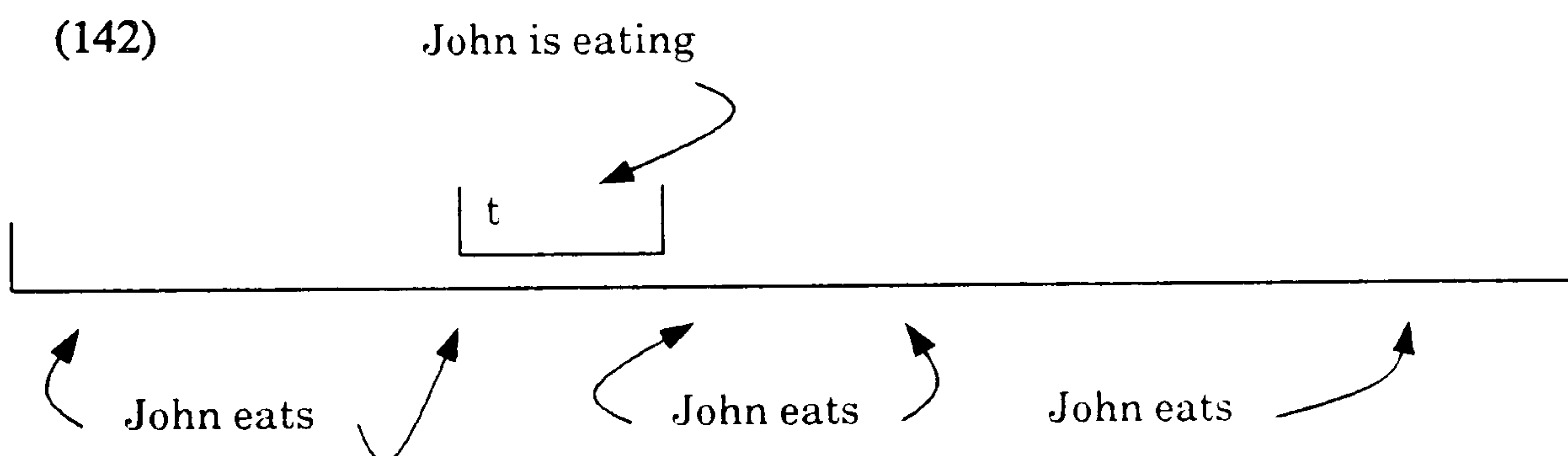
Moreover, by interpreting the problem in terms of "what would have been the case", Taylor's analysis of the imperfective paradox becomes dependent on an analysis of the subjunctive conditional - a notion that is equally hard to define.

Others base their arguments against the existence of the imperfective paradox on the inherent ambiguity of the simple past in a sentence like (141a), or even of some perfects, as in (b):

- (141) (a) Anita painted the hall.
(b) Anita has painted the hall.

It is true that in some contexts neither (a) nor (b) need imply that Anita *finished* painting the hall. In such instances, "Anita was painting the hall" *would* imply both (141a) and (b). This does not, however, prove that the imperfective puzzle does not exist. It only shows that it does not *necessarily* occur when culminated process expressions are used with a progressive auxiliary. It could be restated as follows: *Dempsey was writing a report* could entail *but he never wrote it*; yet *Makepiece was running* cannot entail *but she didn't run* (where *was running* is taken as a past progressive, not as a past futurate progressive).

The original formulation of the imperfective paradox followed attempts made by Scott (1968) and Montague (1973) to give a truth definition for progressive sentences. They claimed that a sentence in the progressive (e.g. *John is eating*) is true at some time *t*, iff the corresponding non-progressive sentence (*John eats*) is true at every moment of some open interval which embraces *t*:

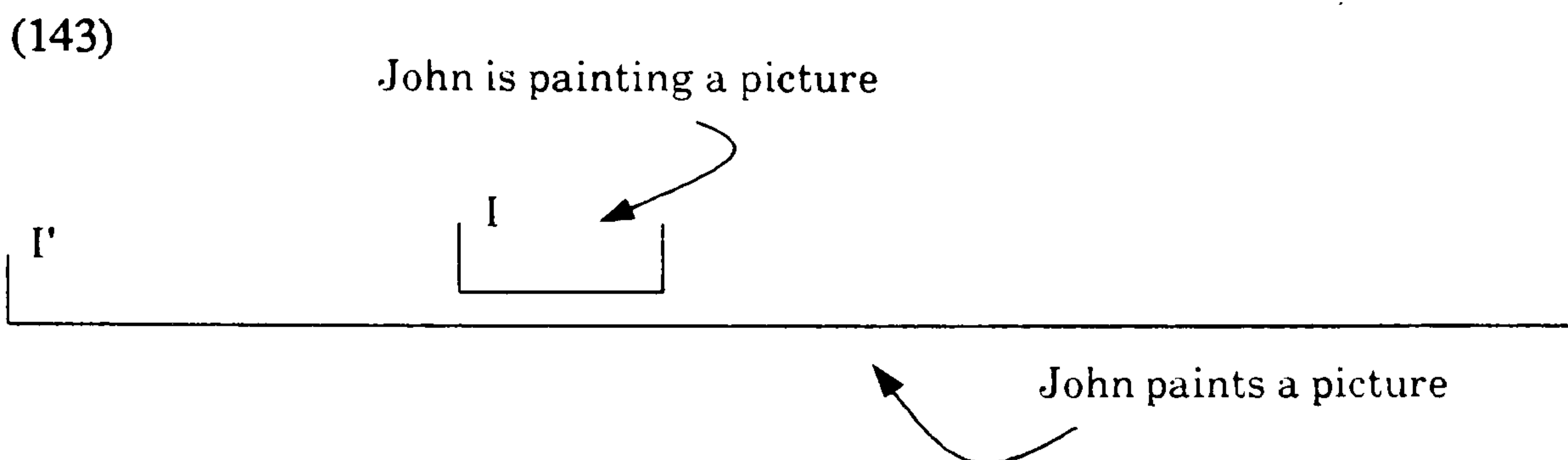


Now Montague's definition for the present perfect says that *John has eaten* is true at *t* iff *John eats* is true at some earlier time. If one combines these two definitions, it becomes clear that *John is eating* entails *John has eaten*: *John is eating* is true at *t* iff there is an interval around *t* (i.e. containing points prior to *t*) such that *John eats* is true at every point in that interval. But if *John eats* is true at some time before *t*, then *John has eaten* is true at *t*. In exactly the same way these truth definitions lead to the claim that *John is drawing a circle* entails *John has drawn a circle*, which is clearly contrary to our intuitions.

This analysis also poses a problem for culminations used with a progressive. *Coe was winning* is true at a time *t* if there is an open interval around *t* for which *Coe wins* is true (i.e. such that *Coe wins* is true at every point in that interval). But culminations like *win* are typically only

true at the *point* at which the race finishes. This makes it unclear what account can be given in the Scott and Montague framework for punctual events occurring in the progressive.

Bennett and Partee (1972) tried to remedy these paradoxical results by introducing the notion of truth with respect to *intervals*. A simple progressive sentence would be true at an interval *I* if there is an interval *I'* such that *I* is a non-final subinterval of *I'*, and the non-progressive form of the sentence is true at *I'*:



Thus *John is painting a picture* can be true at 4:15 p.m. today, if there is an interval starting perhaps 2 weeks ago and ending 4 days from now such that *John paints a picture* is true in that interval. But this also means that there will be a moment, later than that interval, at which *John has painted a picture* is true. This shows that Bennett's and Partee's interval approach also leads to the imperfective paradox.

Another way of accounting - within the framework of interval semantics - for the difference between processes and progressives on the one hand, and culminations and culminated processes on the other, is suggested by Bennett (1977, 1981). In his system, processes and progressives are represented by *open* intervals; culminated processes and culminations are represented by *closed* intervals. According to Bennett's definitions, *Jones is leaving* is true at an interval *I*, if there is an open interval *I'* surrounding *I*, and Jones is in the extension of *leave* at this open interval *I'*. Such an analysis

has the consequence that *Jones is leaving* neither implies *Jones has left* nor implies, in effect, *Jones will have left*, as there is no guarantee that Jones is in the extension of *leave* with respect to a CLOSED interval. (1981: 14-15)

Bennett gives a rather intuitive justification for this approach. One of the intuitions he appeals to is that culminated processes have a start and a finish, processes do not. This, he argues, also results in a different sort of nominalization: culminated processes nominalize into count nouns, as in (144a), processes into mass nouns, as in (144b) (Bennett's examples):

- (144) (a) There was a building of a house by John last year.
 (b) There was some running by John yesterday.

Bennett continues this argument by saying that

this suggests that we're on the right track with "countable" sharp-edged entities (closed intervals) and activities with "measurable" entities whose edges are "vague" (open intervals). (1981: 18)

The parallels between closedness and countability, however, seem to be metaphorical rather than based on topological or other considerations. It is fairly obvious, for example, that a process like *John worked in the garden* is repeatable and countable (*John worked in the garden several times last year*). It is conceivable that Bennett would consider *worked in the garden* in this context to be a culminated process rather than a process, but his definitions in this respect are not very illuminating. The distinction between the *process* of walking and the *culminated process* of walking, for example, is explained away as follows:

My reply is short: I think we understand this difference as well as we understand the difference between a [process] and a [culminated process] generally (1981: 19).

There are clearly a number of flaws in Bennett's approach. One is that he does not specify what exactly the relation is between the process and the culminated process reading of an expression. Another problem is that the distinction between process and culminated process - which basically involve different ways of *describing* the world - is rendered by Bennett as involving a difference in a real world property. One and the same state of affairs can be described by means of expressions belonging to different aspectual types, as in (145):

- (145) (a) I read a poem before I went to bed.
(b) I read poetry before I went to bed.

Since both expressions will, according to Bennett, have different intervals associated with them (a closed interval for the culminated process in (a), an open one for the process in (b)), the description in (a) would imply that that state of affairs started just before and lasted a bit longer than the state of affairs described in (b) - although only one state of affairs is being described (cf. Hinrichs 1985).

An even more serious problem is that purely topologically defined notions will not suffice to make the distinction between the two categories of verbal expressions. Topologically speaking, a process also has an endpoint, even though it may not be the "right" one. Thus, *John is writing a letter* has a beginning and an end point in any real time interval, although that final point may not be the one that makes *John wrote a letter* true. It seems that to determine the truth-conditions for *John is writing a letter* one has to assume there is an interval with respect to which it is true that John was writing with the intention that this writing would result in a letter. *John wrote a letter* would then be true if that result was reached, irrespective of whether

it was intentional or not. (Bartsch 1983: 6). While it is not clear how these notions of intention and result can be translated into purely topological concepts, I do believe they find an easy translation in the integrated system of tense and aspect proposed here. But, again, it is clear that simple point or interval ontologies will not suffice to give a satisfactory account of a phenomenon like the progressive.

Vlach (1981a: 285) provides another argument against purely topological accounts of the progressive. Consider a world in which *Mary wins a race* is true at 3 p.m., and *Harry dies* is also true at 3 p.m. This means that *Mary is winning* starts somewhere before 3, say at t_1 , and *Harry is dying* also starts somewhere before 3, at t_2 . In a purely topologically defined semantics for the progressive, t_1 would have to equal t_2 , since the set of instants at which *Mary is winning* is true would have to be identical to the set at which *Harry is dying* is true. This is clearly wrong.

Dowty's (1979) account of the imperfective paradox is also couched within the general framework of interval semantics; yet, he seems to be going beyond pure topology. His solution involves adding a new primitive function to the definition of a model. This new function assigns to each index (consisting of worlds and intervals of time) a set of worlds called *inertia worlds*. These are possible worlds that are exactly like the actual world up to the time in question. After that point in time, the most natural course of events is supposed to take place. The progressive of a sentence is then said to be true in case the non-progressive is true in all situations which are exactly like the one described, and which proceed "normally". In the example *John is painting a picture* this would mean that the sentence is true at a point in time, e.g. 4:15 p.m., if in any normal course of events John would finish painting that picture at some time after 4:15 p.m.

As Dowty himself recognizes, one problem with this notion of inertia world is that it cannot be defined in terms of a more basic notion such as similarity or probability. It is a primitive function, not needed anywhere else in the model theory of the language (cf. Dowty 1979: 148).

Another problem with Dowty's analysis concerns determining the point which marks the end of the actual world and the start of the inertia world. Consider example (146):

(146) Max was crossing the street when he was hit by a truck.

According to Dowty's analysis, the progressive is true if its non-progressive counterpart is true in every world that is like the actual world up to the point of evaluation and then proceeds

without anything unexpected happening. In (146), the point of evaluation is given in the *when*-clause. This means, however, that the actual world is taken to extend up to the point where Max gets hit; consequently, he will not cross the street in any inertia world since he was already hit in the actual world. The progressive will come out - counterintuitively - as false. It also does not help to change the rule for determining the evaluation point, saying that in the case of (146) the actual world extends up to a point "just before" the reference point given in the *when*-clause. If one could freeze a world where Max is crossing the street a fraction of a second before he gets hit by a truck, then in any normal extension of that world he will still get hit. Again, the progressive would come out as false.

To solve this problem, Cooper (1985: 23) suggests ignoring all the facts introduced by the *when*-clause when considering the truth of the progressive, or all facts in the world except the event described by the progressive.

The first option clearly is not strong enough: interruptions of a process in progress do not have to be described in a *when*-clause, but can also occur across sentence boundaries:

- (147) When I saw him last year on Boxing Day, he was writing his
ninth symphony. The next day, he passed away quietly.

If we settle for the second option, then Cooper's intuition is clearly accurate. What is needed is an account which allows for the inspection of the internal structure of the event described by the progressive clause.

The account of the imperfective paradox is straightforward in the framework sketched so far. Earlier on, a nucleus was defined as a series of preparatory process, culmination and consequent states; it is identified by its goal or culmination. The referent of expressions is closely related to this notion of nucleus: depending on its position in the diagram, an event description may, for example, identify the culmination point itself, or only the consequences, or the whole nucleus.

For a culminated process to occur in the progressive, it has to be turned into a process first. This means that the associated goal or culmination point is not described anymore. It is the preparatory process leading up to the culmination point that is said to be in progress, without implication that the culmination is actually reached. The rather vague ideas of "natural course of events" or "inertia world" that had to be invoked especially to give an account of the imperfective paradox here find a natural expression in the concept of a process, associated with and identified by a culmination, irrespective of whether that culmination point is actually reached.

Indeed, for a notion like inertia world to have any explanatory impact, one has to look at the whole event (or rather: its nucleus) under consideration - in the case of (146): the process, tending towards a specific culmination point of Max crossing the street. The truck hitting Max is not an interruption of the natural course of events; it *is* the natural course of events. Yet, we clearly experience it as an interruption of something. That is because the "inertia" is not in the world but in Max's plan (which omits certain crucial details of the real world). The truck hitting Max is an interruption of Max's planned event (or of the intended action we ascribe to Max), and because of this, it is an interruption of the structure we associate with that event.

This short overview of some of the literature on the imperfective paradox shows that accounts couched in the simpler point and interval ontologies are not satisfactory, or have to resort to *ad hoc* notions (like inertia world) that are not used anywhere else in the theory. With the somewhat more complex ontology presented here, an account of the imperfective paradox becomes rather straightforward. This account is, moreover, based on notions that also play an important role in other parts of the theory.

Ours is not the first account to argue in favour of a more complex ontology to handle the imperfective paradox. Parsons (1984), e.g., contains an analysis of a fragment of English based on a Davidsonian event ontology (cf. chapter 3). Parsons suggests an analysis of natural language in terms of eventualities that either *hold* or *culminate* at a point in time. Following Bennett's approach, he describes the difference between a progressive and a non-progressive as residing in the question whether the sentence requires for its truth that the eventuality actually culminates or only holds for a while. Thus (148) gets a translation as in (148a), saying that there is an event *e* of *crossing*, with *Agatha* as the agent and *the street* as the object, and this event culminates at a time *t*.

(148) Agatha crosses the street.

(a) (e)[crossing*(e) & Agent(Agatha*, e)
& Object(the street*, e) & Culminates(e,t)]

The progressive counterpart of (148) gets a translation as in (149a), which says that the event holds without implying anything about its culmination.

(149) Agatha is crossing the street.

(a) (e)[crossing*(e) & Agent(Agatha*, e)
& Object(the street*, e) & Hold(e,t)]

Parsons' analysis does not attempt to analyse the truth-value of the progressive sentence in terms of the truth-value of the non-progressive. (149a) does not say anything about the event culminating (as in 148a), or about the non-progressive counterpart of the VP; it only states that

the event holds at all moments in an interval. This is very different from the Scott and Montague analysis where the *non*-progressive version of the sentence had to be true throughout an interval.

Parsons is not entirely clear about the difference between events that hold as opposed to those that culminate. On the one hand, he pledges allegiance to Bennett's interval approach, describing the difference as that between an event being associated with an open or a closed interval:

the distinction between open and closed intervals is simply a way of *coding* whether or not an eventuality culminates, without using any notions that are not definable by means of the resources of pure interval semantics (Parsons 1984: n.p.)

However, the notion of *eventuality* does provide Parsons with another way of talking about intervals:

Suppose that we have pinned down the period of an eventuality precisely, except that we do not yet know whether this interval includes its endpoints. We do not decide this by more careful measurement. We just *stipulate* that if the eventuality culminates, then its agent is in the extension of the relevant verb at the closure of that somewhat ill-defined interval. (Parsons 1984: n.p.)

This means that first in the analysis comes the eventuality, with - we may assume - its "natural" beginning and endpoint. Once an interval or other type of period gets associated with it, the endpoint of that period will be determined by the endpoint of the eventuality, thus assuring that we are looking at a period with the "right" endpoint when determining the truth-value of a sentence. Parsons gains this advantage over Bennett by taking events to be more basic in his ontology, letting periods to be derived from them.

The observation made earlier on - that drawing a circle is clearly different from drawing a triangle, although in neither case is there a circle or triangle already in existence - follows rather nicely from our account of the imperfective paradox. The events talked about are identified by means of their culmination point, viz. the point at which triangle and circle are finished. Although these points need not be reached, they do mark a clear difference between the two events and in the preparatory process leading up to that culmination point. Any further specification of the coming into existence of the object would make a uniform account of the progressive impossible (cf. Bennett 1977: 504-508).

Dowty has pointed out a peculiar characteristic of the English progressive for which his inertia world approach provides a straightforward account: if two sentences A and B cannot be true simultaneously, then the progressive of A and the progressive of B cannot be true simultaneously either. A coin cannot come up heads and tails at the same time; likewise, a coin in

mid-air is not *coming up heads* and *coming up tails* at the same time. In Dowty's approach, this phenomenon is taken care of by the fact that the non-progressive has to be true in *every* inertia world. Since there is no world in which the coin can come up heads *and* tails, it is certainly not true in *all* inertia worlds that it comes up thus.

However, inertia worlds are not the only way of accounting for this phenomenon. In the approach defended here, events are defined as complex structures, identified by their goal or culmination point: a sentence like *the coin is coming up heads* describes a preparatory process, associated with and identified by the culmination *the coin comes up heads*. This is obviously incompatible with the assertion *the coin is coming up tails*, since this requires us to add to the same event structure a preparatory process identified by the culmination *the coin comes up tails*. If we think of the sentences in a consistent discourse as describing a consistent (set of) event structures, then the impossibility of the simultaneous truth of the two progressive sentences follows automatically. It is also obvious why this approach does allow the (well-formed) discourse (150) (suggested by Cooper 1985: 21).

(150) First the coin was coming up heads, but then it was coming up tails.

5.3. Perfects

In this section, I will first discuss some of the descriptive accounts of the perfect. I will argue that these are vague in the sense that they make unprincipled distinctions between different uses of the perfect, without explaining why the perfect should fulfil such an arbitrary looking collection of functions. Next, I will give a more unified account, based on the nucleus ontology introduced before. I will compare this briefly to approaches using a simpler interval ontology. Finally, returning to the descriptive work, I will compare the account presented here in more detail to McCawley's and Comrie's, which constitute the most principled and best known descriptive accounts of the perfect.

5.3.1. Some semantic descriptions

Semantic descriptions of the perfect auxiliary are notoriously vague: they ascribe to it a variety of seemingly unrelated meanings, at the same time ignoring the fact that these distinctions very often depend crucially on adverbials or other expressions occurring in the sentence.

The most general explanation of the present perfect is that it covers a past-to-present period of time, as in (151):

(151) Phil has worked in London since 1958.

Not only does this interpretation depend on the adverbial expression, but - the other way round - adverbials denoting such a time-span also occur with a simple past, as in (152) (although this may be restricted to American English):

(152) Up to now, I always had a good job.

Moreover, the period from 1958 to the present referred to by the adverbial in (151) is not necessarily a period *throughout* which Phil worked in London. (151) could be an assertion of the fact that, in the period starting in 1958, there is at least one occasion on which Phil worked in London.

Thomson & Martinet (1974) categorize the perfect in (153) as a perfect of a separate type, describing a state of affairs that started in the past but that ends at the moment of speech (1974: 107):

(153) I haven't seen you for ages.

However, a mere change in personal pronoun, would force them to categorize (154) as a different sort of perfect, viz. one that started in the past but does not necessarily finish at the moment of speech:

(154) I haven't seen him for ages.

According to Quirk e.a. (1972: 44), a perfect is used to describe actions that took place at an indefinite time in the past, as in (155), and this, they claim, contrasts with the simple past which refers to a definite past time:

(155) I have seen the Mona Lisa.

But (156), an example of the so-called "recent" past, describes an event that took place at a definite time in the past, and yet the present perfect is quite acceptable:

(156) I have just met your brother.

Again, the distinction seems to depend crucially on the presence of adverbial expressions. Without these it is often virtually impossible to decide which category a perfect belongs to (cf. Allen 1966: 67). The result of this descriptive work can perhaps best be summarized in the words of Thomson & Martinet (1974), who - after describing 20 different uses of the present perfect - sum up its basic meaning in the rather meaningless phrase: "This tense may be said to be a sort of mixture of present and past" (105).

5.3.2. Consequent states

In the previous chapter, the function of the perfect was described as mapping a culmination into its consequent states. This function can be represented as follows:

(157) Perfect: CULMINATION \rightarrow CONSEQUENT STATE

This means that the (present) perfect describes the consequent states of the core event as (currently) holding. Hence, a sentence like (158) is true if the consequences associated with the culmination of *John reaching the top* (e.g. *John being at the top*) are currently in force.

(158) Max has built a house.

To be able to use a culminated process expression like *climbing Mount Everest* with a perfect auxiliary, it first has to be coerced into a culmination. Requiring such a transition might seem unnecessary since a culminated process already implies the existence of a culmination with consequences to which the perfect could refer. But consider (159) as a possible rendering of the nucleus associated with *climbing Mt Everest*:

(159) climbing the mountain being at the top
 //////////////////////////////////////
 |
 reaching the summit
 of Mt Everest

If a perfect could be used to single out the consequences of a nucleus associated with a culminated process expression, then *having climbed Mt Everest* could be used to refer to the state of having reached the summit or being at the top. However, this does not seem to be the case. A reporter who has managed to establish radio contact with a mountaineer who has just reached the top of Mt Everest is unlikely to ask

(160) Have you climbed Mt Everest yet?

The question rather seems to concern consequences of the culminated process as a whole. This fact is captured by making the perfect coerce the culminated process to become a culmination. The transition network allows this to happen if the entire event of climbing Mt Everest is treated as a single unit by making it into a point, so that it can become a culmination in its own right. The perfect then delivers a rather different kind of consequent state.

Process expressions like *work in the garden* normally cannot occur in the perfect (cf. Mittwoch 1982: 117), unless they have been turned into a culminated process first, and are thus being associated with a particular culmination point:

- (161) ?I have worked in the garden.
 ?I have run.
 ?I have typed letters.

Stative verbs (162a and 163a) do not normally take a perfect auxiliary (cf. the (b)-examples). A transition has to be made first to the culmination node. The first step in this transition path is changing the states into processes. Once this is done, a number of routes can be taken through the aspectual network. One of them involves the use of explicit linguistic material to facilitate transitions: a *for*-adverbial turns the process into a culminated process. The perfect can then be used to refer to the consequences associated with the reaching of that particular culmination point (as is illustrated in the (d)-examples).

- (162) (a) ...know the answer.
 (b) ?John has known the answer.
 (c) ...know the answer for years.
 (d) John has known the answer for years.
- (163) (a) ...be empty.
 (b) ?The house has been empty.
 (c) ...be empty for several months.
 (d) The house has been empty for several months.

Since the meaning of the perfect depends crucially on the notion of consequences, it is important, for example for the construction of a database where temporal information from natural language can be stored, to keep track of the consequences that we associate with a particular core event. This will result in sequences of events that are related through consequentiality or through some other relevant relation (like enablement). In what follows, these consequential sequences will be referred to as *episodes*. The definition of the perfect can then be reformulated as follows: the perfect of a core event is true at some time if some event or situation which is consequent upon that event (that is, subsequent to the core event and belonging to the same consequential sequence or episode), is in force at that time. It should be borne in mind that there is no real difference between a nucleus and an episode: the term episode merely refers to a nucleus about the constituent parts of which there is further information available - i.e. which events form part of its preparatory process and which events are part of its consequences. The use of episodes in the representation of knowledge extracted from natural language text will be returned to in chapter 8.

The account given here also explains why the classic example (164a) is ruled out as infelicitous, whereas its passive counterpart is not:

- (164) (a) ?Einstein has visited Princeton.
 (b) Princeton has been visited by Einstein.

If, in the absence of any other obvious candidate, we take Einstein's life to be the consequential sequence we are currently talking about, then (a) cannot be used felicitously to refer to a part of that sequence, since at the moment of speaking the entire consequential sequence is finished. However, (a) *can* be uttered felicitously to refer to the same event when the consequential sequence is not Einstein's life but, for example, the history of Princeton University - a sequence which is not over yet. And for the same reason, (164b) can be used to refer to an event on the sequence representing the history of that particular university.

It should be clear from these examples that, as for all transitions in the aspectual network, the exact nature of the consequences is determined by our general world knowledge. In the case of a culmination expression like *reach the top*, the consequence that comes to mind most easily is that the person talked about is still at the top of the mountain:

- (165) John has reached the top.

This need not be the case, however. It is possible, for example, to utter (165) while it is clear that John is not at the top at the moment; this would mean that the speaker is asking the hearer to think of other consequences that *reaching the top* may have.

Similarly, in the case of example (166), obvious consequences could both be *John's being at the office*, or *John's not being here*.

- (166) John has gone to the office.

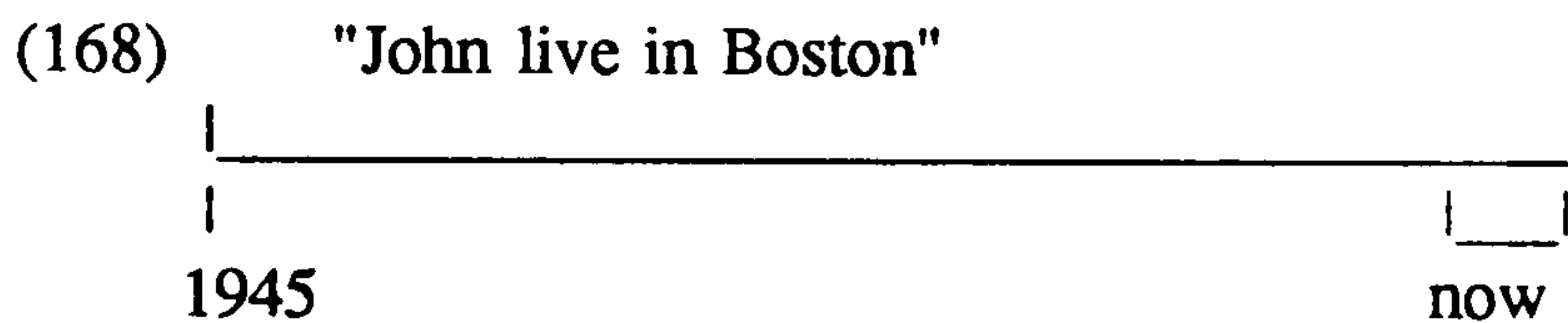
And in (167) it is not so much the subject of the sentence that is experiencing the consequences, as the speaker and his wife:

- (167) We can't come to your party. The police have arrested my wife.

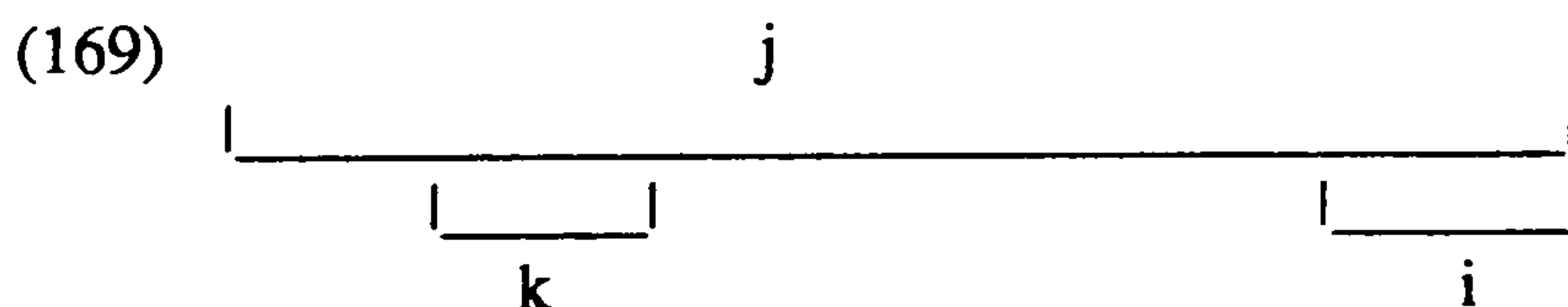
The last two examples come from McCawley (1981) who argues that it would be impossible to give an analysis which would correctly predict what consequences the sentence describes. This observation is certainly correct, since the exact nature of the consequences is determined by the nature of the core event and by our (general and specific) world knowledge associated with that event. But this does not render false an analysis of the perfect in terms of reference to the consequent states: the use of the perfect indicates that there is some continuing result. It is not part of natural language semantics to predict what could be possible consequences for any given event. But it would constitute a bad case of misunderstanding if (167) was processed without realizing that the speaker conveyed a consequential relation between his wife's arrest and their absence from the party.

Our analysis also proves to be more specific than descriptions of the perfect in terms of an "extended now". This view of the perfect was most influentially defended by McCoard (1978). He claims that the perfect locates an event somewhere in a period which starts in the past, and which extends up to (and includes) the moment of speech.

This is the view taken up in interval semantics by amongst others Bennett & Partee (1972) and Dowty (1979). Their truth-definitions for a perfect expression like *John has lived in Boston since 1945* involve the identification of a large interval (in this case the interval referred to by *since 1945*) of which "now" is a final subinterval: *John live in Boston* is then required to be true with respect to that larger interval. This is represented schematically in (168), where the large interval surrounding "now" represents the "extended now".



Tichy (1985) points to some inaccuracies in this approach when one tries to deal with interrupted activities (as in *John has lived in Boston on and off since 1945*). This flaw seems to be due, however, to the general interval framework, rather than to the formulation of the rule for the present perfect. It was adapted to a homogeneous interval logic by Heny (1982: 142) and Richards (1986). Their definition says that $\text{HAVE}(\phi)$ is true with respect to an interval i , if i is a final subinterval of some interval j , and ϕ is true with respect to some k , which is a non-final subinterval of j . Schematically, this can be represented as follows:



On this analysis, *John has reached the top* is true at i if *John reach the top* is true at k . Note that the definition does not just state that interval k precedes interval i , but opts for the more complex specification that both intervals are part of a larger interval. This stipulation is crucial, since without it, the definition of the perfect would be the same as that of the simple past. The use of the surrounding interval j can be seen as an attempt - in interval terminology - to capture the fact that at i the consequences of whatever happened at k are still being felt. But it should also be clear from (169) that in purely topological terms, the definition *does* boil down to the stipulation that k precedes i . Since no content can be given to j , there is no way of expressing in this ontology what sorts of events are allowed to happen *in between* k and i . Yet, as we tried to show before, this is crucial for a definition of the perfect. For example, if k is an

event of Ellie spilling her coffee, and *x* (in between *k* and *i*) is the event of Ellie cleaning up the coffee, it would be hard for her to find a felicitous use of the perfect expression (170) at *i*:

(170) I have spilled my coffee.

On the other hand, if she were to utter (170) at *i* in the circumstances just sketched, she would be asking us to consider consequences of her spilling her coffee other than there being spilled coffee on the floor. In this reading, *k* and *i* would still be part of the same consequential sequence or episode.

Our analysis of the perfect in terms of the consequent state of the core event being in progress also explains the ungrammaticality of a sentence like (171):

(171) *He has arrived yesterday.

In the analysis offered here, the sentence would refer to the consequences of *arriving yesterday* as opposed to arriving some other time. But most of what we think of as consequences of events are *independent* of the time of occurrence of the event: it is not clear why *arrive yesterday* should have consequences which are different from *arrive two days ago*. If, however, certain situations *are* a consequence of an event taking place at a particular time, then that time can be referred to by means of an adverbial expression, and the perfect auxiliary may be used. Thus, a superstitious person believing that a disastrous situation is the result of someone's arriving at an unlucky moment can say:

(172) Oh God, he has arrived on Friday the 13th !

But even on Saturday the 14th, (171) cannot be used felicitously, for it would not provide the essential information about the date, thus flouting Grice's maxim of quantity.

Our analysis of the perfect further explains a number of meaning phenomena involving *when*-clauses.

- (173) (a) When the guests had arrived, the speeches began.
(b) *When the guests had arrived, the chairman was speaking.

The consequences of a state of affairs referred to by the perfect have to be in force at the reference time. Since there is a perfect form in the subordinate clause, its consequences are in force at the reference time introduced by the *when*-connector. This reference time is also the evaluation point for the main clause. So, in (173a), at the point where the main clause is evaluated, the consequences of the subordinate clause are in force. This explains why we try to find a consequential or other relation between the subordinate clause and the main clause when we interpret (a). It also accounts for the observation that a perfect form cannot be used in combination with a *when*-clause indicating simultaneity (cf. 173b). Since we usually think of

consequences as starting to take place sometime after their being caused, *when* will automatically be taken to mean *just after and because of* rather than *just as*. We will come back to this phenomenon, and to other intricacies involving *when*-clauses, in chapter 6.

5.3.3. McCawley's and Comrie's 4 types of perfect

The hypothesis advanced here - that the perfect has only one temporal meaning - is not new (cf. Partee 1972; Inoue 1979). Yet, it seems to be inconsistent with the view defended in most descriptive accounts, viz. that the perfect has a wide collection of different meanings. The most obvious argument as to why the unified view is to be preferred to approaches that distinguish different uses of the perfect, is to show - as I did briefly at the beginning of section 5.3.1 - that these different types can only be distinguished on the basis of linguistic elements other than the perfect auxiliary. The question that still remains, however, is why is it that adverbials and other expressions can have such an influence on the meaning of the perfect expression.

It is not possible within the limited scope of this section to disentangle all the definitions proposed in the vast literature on the perfect, and to compare them with the unified account proposed here. I will therefore restrict myself to a comparison with McCawley's (1971, 1981) and Comrie's (1976) accounts.

McCawley and Comrie distinguish four separate uses of the present perfect:

(a) the universal perfect or perfect of persistent situation - which indicates that a state of affairs prevails throughout some interval stretching from the past into the present:

- (174) I've known Max since 1960.
We've lived here for ten years.

(b) the existential or experiential perfect - which indicates that an event occurred at least once in a period that extends from past to present:

- (175) I have read 'Principia Mathematica' five times.
Bill has been to America.

(c) the stative perfect or perfect of result - which indicates that the direct effect of a past event still holds, or that a present state is the result of some past situation:

- (176) I can't come to your party tonight - I've caught the flu.
Bill has gone to America.

(d) the hot news perfect or perfect of recent past:

- (177) Malcolm X has just been assassinated
I have recently learned that the match is to be postponed.

First, the perfect of hot news can only be distinguished from the other perfects because of the appearance of an expression like *just* or *recently*.

The stative perfect or perfect of result is most closely related to our description of the temporal referent of the perfect in terms of consequent states. As McCawley points out, the distinction between this and other types is made on the basis of the type of verb the different perfects take: the "stative" sense occurs mostly with culmination verbs, as in (176). This is because culminations have well delineated core events with a strong sense of possible consequent states associated with them.

The universal and existential perfects both involve a quantifier ranging over an interval stretching from past to present. The difference between them lies in the fact that in the first case this is a universal quantifier, and in the second case an existential one. But in fact, both uses of the perfect are crucially dependent on the different adverbial expressions, viz. the *for* and *since*-adverbial in (174), as opposed to the frequency adverbial in (175). And, as we saw before, the compatibility of the adverbial with the verb is determined by the type of event the verbal expression in question describes: the verbs in (174) (*know*, *live*) lend themselves to a continuity reading and cannot normally occur with a frequency adverbial; a culminated process like *read a book*, or *go to America* on the other hand, refers easily repeatable events (cf. 175). In other words, the difference between the existential and the universal perfect depends on the aspectual character of the event described in these sentences.

It is sometimes argued that sentences with *since* and a perfect are ambiguous between a universal perfect and an existential one:

(178) Pete has worked in the US since 1972.

It is misleading, however, to ascribe this ambiguity to the perfect auxiliary. The ambiguity also arises in the simple past:

(179) Harry worked for GM.

(179) can be interpreted to mean that Harry worked for GM once, several times or habitually for an extended period. In fact, this ambiguity even shows up in the underlying tenseless sentence (for this use of "tenseless", see chapter 7).

(179') The career advisor recommended that Harry work for GM.

The difference between the universal and the existential reading clearly depends on the chosen interpretation of the basic expression and it could be argued that it should not be dealt with in the semantics of the perfect.

From this account it follows that the main difference between a present perfect and a perfect progressive lies in the fact that they refer to the consequences of different entities: the former pertains to possible consequences of *John write a novel* (as is illustrated in 180a), the latter of *John be writing a novel* (as in 180c). This accounts for often noted differences between these

two constructions:

- (181) (a) I've cleaned the windows.
 (b) I've been cleaning the windows.

The (a) example implies that the culmination point of cleaning the windows was reached, i.e. that the job was finished, and it would be odd to continue with *but I haven't finished them yet*. The consequences that can be most readily associated with this probably pertain to the cleanliness of the windows. In the (b) example, the original culmination point (i.e. *finish cleaning the windows*) is stripped off. The progressive state of cleaning the windows is then associated with a new, arbitrary culmination point. The consequences of this, described in (b) are, possibly, that *some* windows are clean. I described the newly added culmination point as "arbitrary" since it is just added to the process without any indication of where it is to be found. It might even coincide with the original culmination point. For this reason, (181b) could be used even if the job is finished. The consequences associated with *I be cleaning the windows* could be anything from *being tired* to *not having put the ladder back where it belongs*. They can be different, however, from the consequences associated with *I clean the windows*.

This also explains the observation made by Quirk e.a. (1985), that it is hard to tell the difference between (182a) and (b):

- (182) (a) He's lived in that house for 13 years.
 (b) He's been living in that house for 13 years.

Since *live* is not a culminated process or culmination, it does not have consequences of its own. In both examples, a culmination point is provided by the *for*-adverbial. It then becomes hard to see what the difference is between the consequences of *live here for 13 years* and *be living here for 13 years*.

5.5. Conclusion

In the previous chapters, it was argued that a vital preliminary to a satisfactory and unified semantics of natural language temporal expressions is the identification of the ontology underlying their meaning representations and of the nature of a temporal referent. Chapter 4 sketched what this ontology looks like and described how it is embodied in a transition network of aspectual types.

In this chapter, this ontology was used to give an account of the semantics of a variety of expressions in English, comprising aspectual auxiliaries and certain temporal/aspectual adverbials. In the next chapter, the same approach will be used to give an account of the temporal

structure of discourse. I will in particular discuss how *when*-clauses or simple sentences in narrative can be used to bring into focus a reference event with respect to which later clauses are to be interpreted.

Chapter 6

The temporal structure of discourse

6.1. Introduction

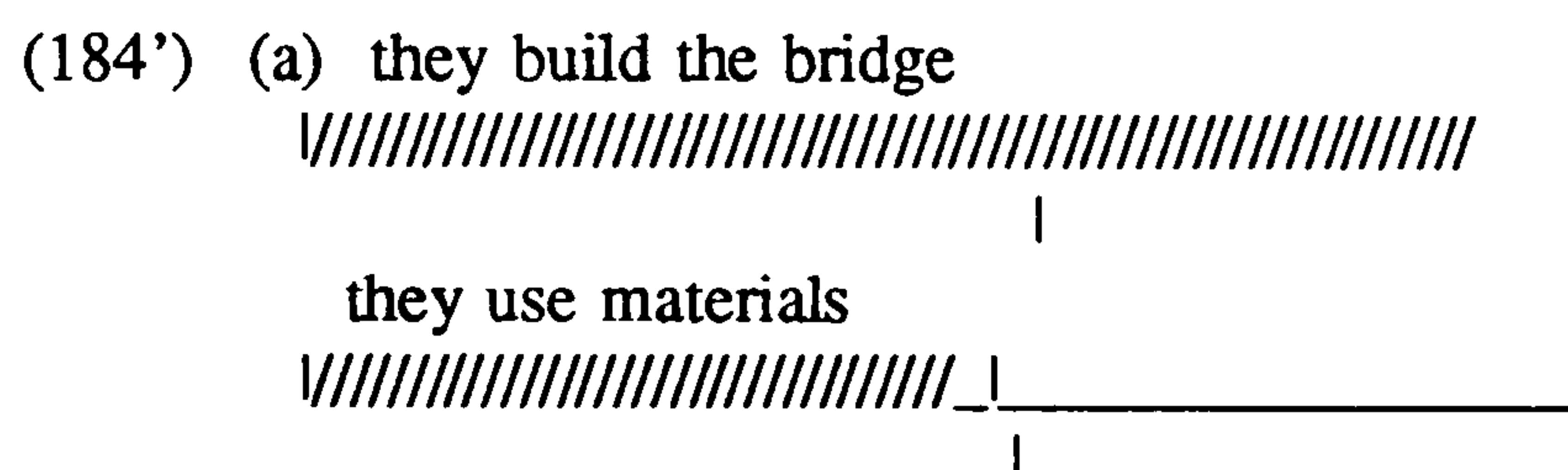
The starting point of the earlier chapters of this dissertation was that the comprehension of discourse involves the construction of a model of the events and situations talked about in the discourse. Or, more accurately, the listener tries to build a structured representation of the temporal relations the speaker *claims* there to be between these states of affairs. Tenses were said to be anaphoric in nature in that they can pick up another (previously introduced) event from this model with respect to which the new event will have to be situated. Further information as to how these events are to be connected in the model under construction can be provided by certain explicit clues in the text, as well as by knowledge about the discourse situation and about the world in general. These ideas, by no means novel to the cognitive science community, were elaborated upon in chapters 1 to 3.

In these chapters, it was also claimed that the problem with earlier referential accounts of temporal phenomena lies in their rather simplistic view of the nature and structure of the basic entities that tenses anaphorically refer to, and that make up the event model of the discourse. It was claimed that more complex entities than mere points or intervals are involved, and that the resulting event structure is rather different from the linear time concept familiar from physics or temporal logic. In chapters 4 and 5, the nature of this temporal referent was examined. It was shown how adopting it as a basic entity in the domain underlying temporal meaning representations allows for a unified treatment of a great many phenomena in the area of temporal reference.

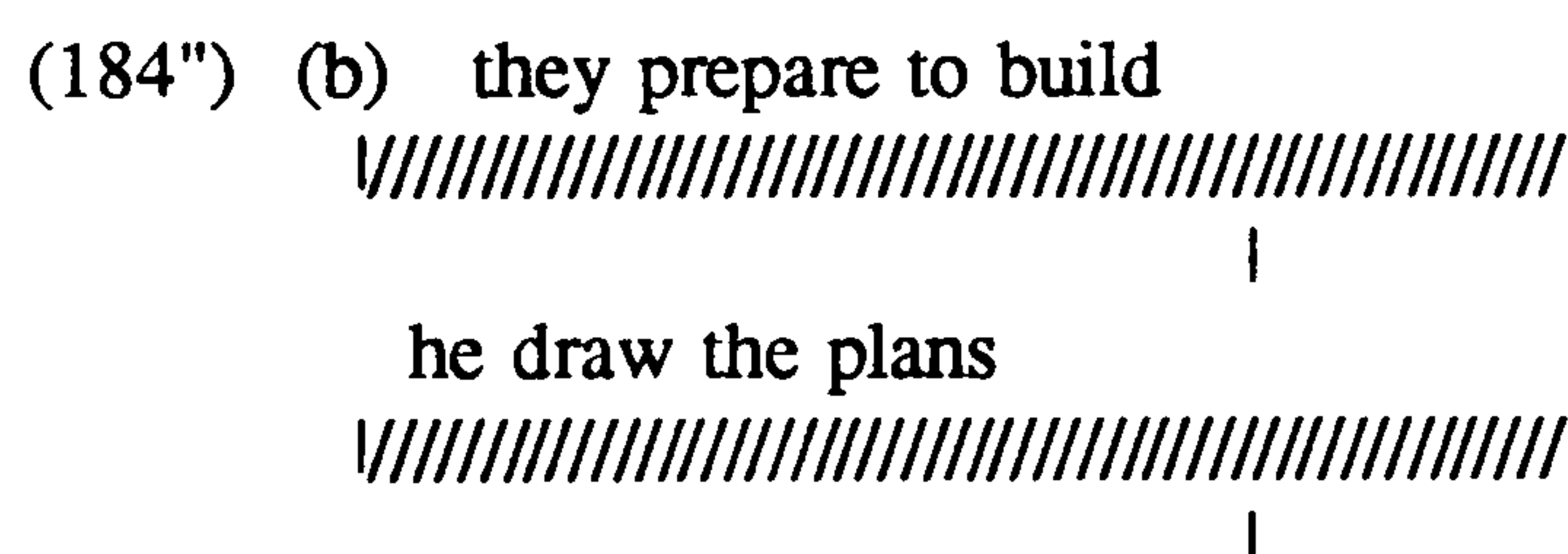
In this chapter, we will return to the problem we started off with, viz. how are the temporal referents that are provided by tensed clauses connected into a structured model. The construction typically used to set up such a referent in the discourse model for a subsequent clause to refer to is the *when*-clause. It is to an account of this construction that we turn first. For reasons of comparative clarification, *while*-clauses will be discussed briefly as well.

The main clause event can be situated anywhere along either of these nuclei, provided the chosen location is supported by knowledge about this particular building event or by general world knowledge. The main clause in example (a) is part of the preparatory process leading up to the building of the bridge. In other words, our world knowledge supports the reference

time of this main clause (a process expression) to be situated in the preparatory part of the nucleus in (184'):



The main clause in (b) describes an event which is also part of a preparatory process - but of a quite different preparatory process than before, as was illustrated in (184''). The reference time of this main clause (a culminated process expression) is to be situated on the preparatory part of that nucleus, as is illustrated here:

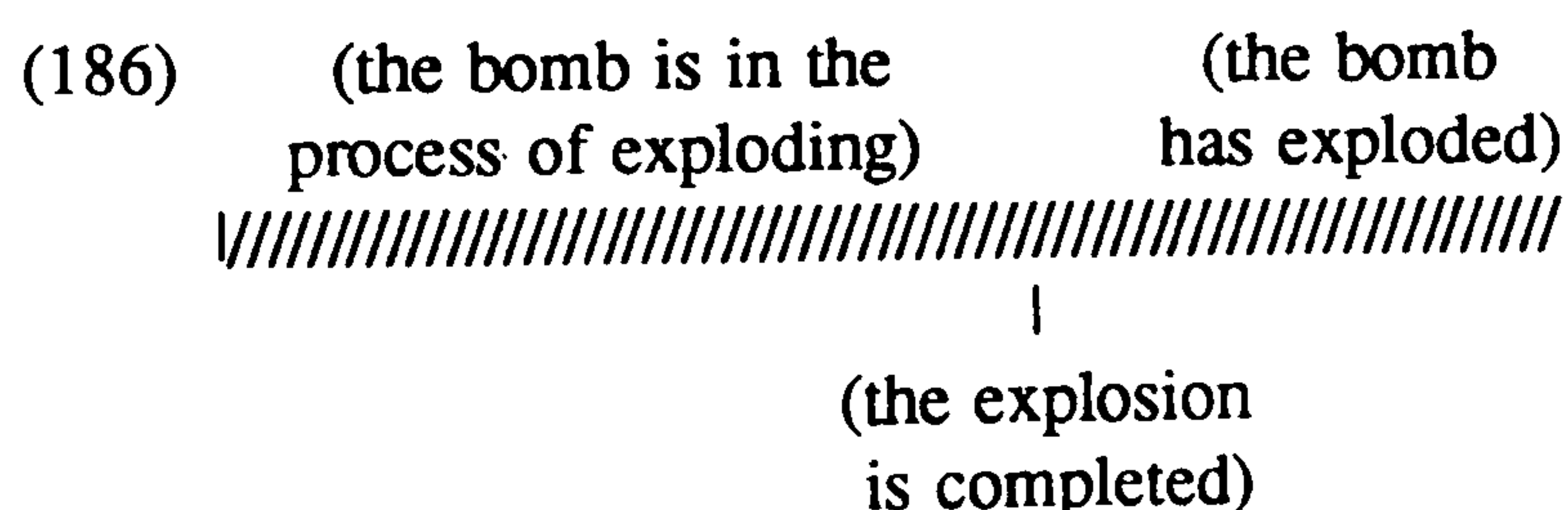


Example (c), finally, is like (a) in giving rise to the nucleus in (184'), but pragmatics demands that the main clause be situated somewhere in the consequences of building the bridge.

When *when* is combined with a culmination, as in (185), it also maps it into a culminated process expression:

(185) When the bomb exploded...

Again, there are two ways in which a complete nucleus can be associated with such an event. One is to bring into play the preparatory processes that are inherent in the culmination (but that are normally not referred to). The resulting nucleus looks as follows:



This type of nucleus allows one to look "inside" the apparently punctual event of an explosion, as in (187):

(187) When an atom bomb explodes, it goes through three phases.

Another and more common way of associating a complete nucleus with a culmination expression is by taking the explosion to be an unstructured part of a nucleus for which episodic memory provides a preparatory process and possible consequences. Such a nucleus can be represented as follows:

(186') preparing to explode the bomb have
 the bomb exploded
 ///
 |
 the bomb explode

Notice that the preparatory process in (186') is essentially different from that in (186); the consequences are also different, but less strikingly so.

It is a nucleus as in (186') that *when*-clauses usually conjure up when combined with culmination expressions. Once such a nucleus has been determined, world knowledge will help decide where to situate the main clause event:

- (185) (a) ...it was *me* who pushed the button.
 (b) ...it destroyed most of the bathroom.
 (c) ...we ran for cover.

Often, the nature of the consequentiality relation - and therefore also of the temporal order between subordinate clause and main clause - remains undecided, as in (188):

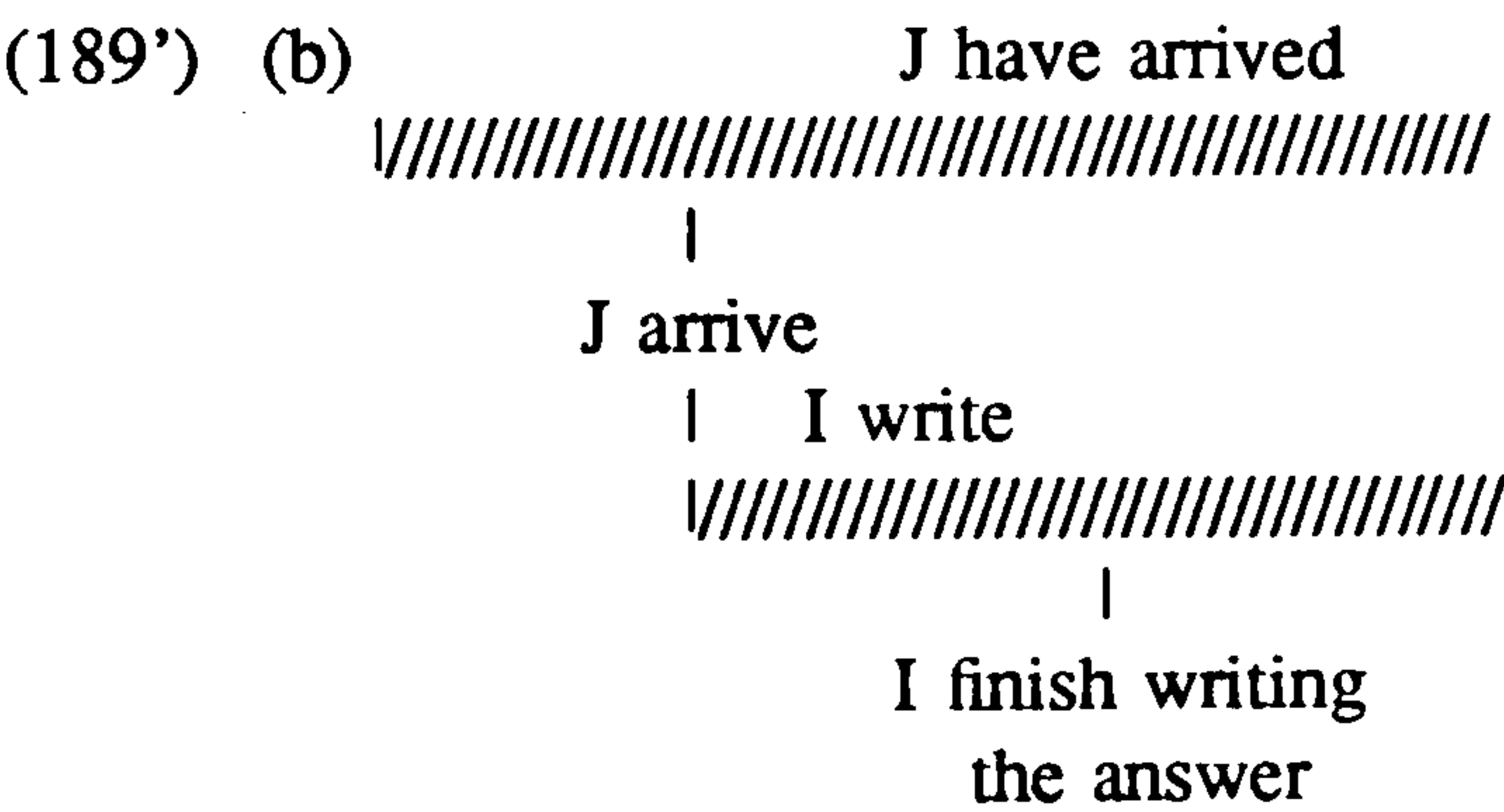
(188) When Nikki Lauda won the race, the best technicians worked on his car.

World knowledge is not a clear enough guide to help the reader decide whether *the best technicians worked on his car* was one of the facts that enabled Lauda to *win the race* or whether it followed it as one of the consequences, (i.e. that it was because he won the race that he was given the best technicians). A cooperative speaker can disambiguate (188) by using a past perfect, either in the *when*-clause or in the main clause. But in either case, (188) means *more* than what would be expressed by using a *before* or *after* connective.

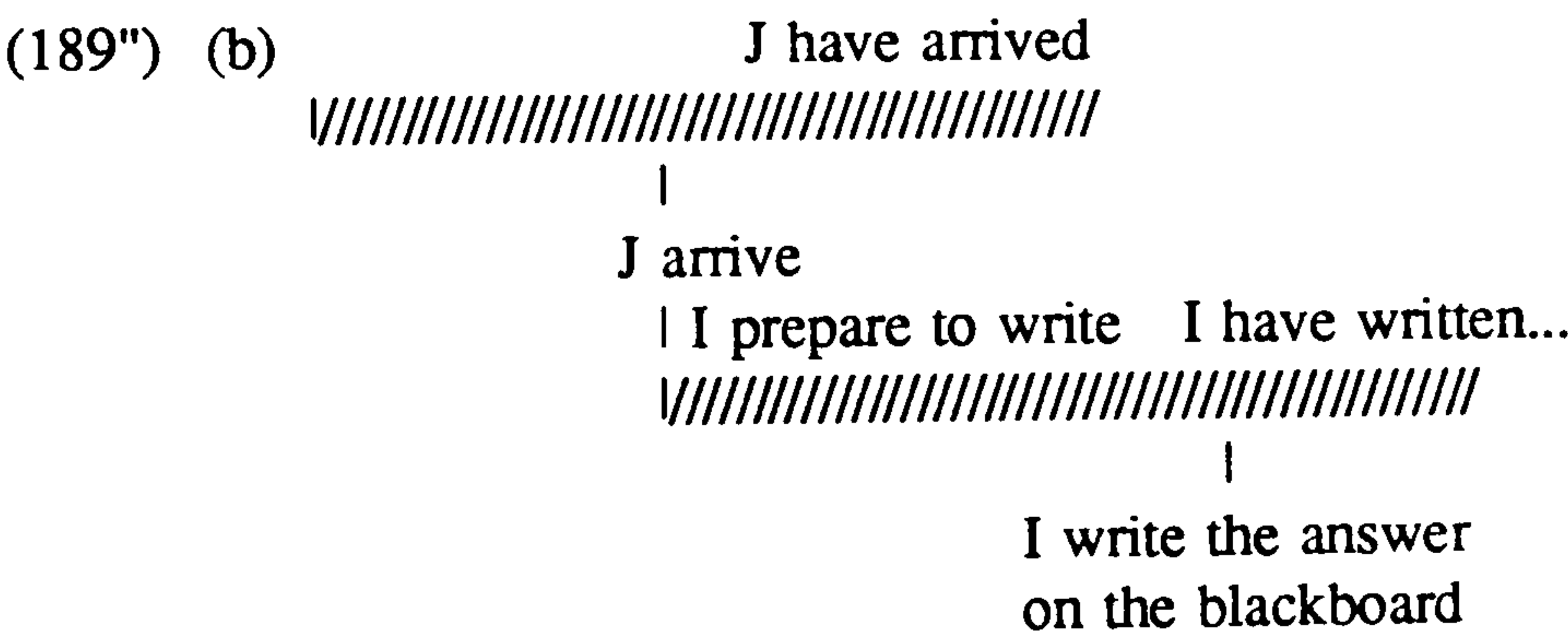
When a *when*-clause with culmination expression is followed by a main clause containing a process (189a) or culminated process (189b), the main clause often gets an inchoative reading:

- (189) (a) When Lou left, Joe worked really hard.
 (b) When John arrived, I wrote the answer on the blackboard.

There is no need, however, to invoke a functional transition on the main clause event to explain these inchoative readings: they follow rather naturally from the way the nuclei are linked up with each other. Consider the (b)-example. The *when*-clause has associated with it a complete nucleus consisting of the core event (*John arrive*) preceded by a possible preparatory process and followed by associated consequences. The main clause, a culminated process, also provides a complete nucleus which has to be linked up to the nucleus associated with John's arrival. It is rather implausible that *writing the answer on the blackboard*, or even part of it, would have "enabled" or "caused" John's arrival. World knowledge seems to suggest, rather, that the nucleus associated with the main clause will have to be attached as the first immediate consequence of John's arrival. If we let the process of *writing* start at the point of John's arrival (or as the first consequence of it) it will be felt to have an inchoative reading. This is illustrated in (189'):



This is not the only interpretation of (189b), however. As always, the culminated process expression in the main clause as a whole can be taken to refer to the culmination of a nucleus. This culmination is then situated as the first consequence of John's arrival, as in (189"b):



Although the preparatory process of *writing the answer* may still be taken to start at the point of John's arrival, it does not give the actual process of writing an inchoative meaning,

To summarize, the constraints *when* places on possible interpretations of the relation between

subordinate and main clause are quite strong. First, episodic memory has to be searched for an occurrence of the event described in the *when*-clause; general and specific knowledge about this event has to support the association of a complete nucleus with it. Secondly, world knowledge also has to support the consequentiality relation between the events in subordinate and main clause. As a result, many sentences containing *when*-clauses sound strange or are considered infelicitous, because too much context has to be imported to make sense of them. It is, incidentally, striking that most accounts of the semantics of this connective (e.g. Heinamaki 1974, Miller & Johnson-Laird 1976, Ritchie 1979) restrict themselves to *when*-clauses containing culmination expressions (or use stative subordinate or main clauses, about which more later). Because of these restrictions and the important role played by the context it is quite hard to systematically discuss all possible combinations of aspectual types in subordinate and main clause. I will therefore only briefly discuss some of these apparently infelicitous examples, merely to show that this very infelicity is predicted by the theory and depends on our knowledge about the events involved.

It is not always easy to associate a period of preparation with a culmination. This is the case, for example, when the culmination describes an event which is too insignificant to think of as having a preparation leading up to it:

(190) ?When the car started, I turned the ignition key.

In a context where the culmination in the subordinate clause *does* describe an important event (e.g. in a court case where one is trying to establish who started the car) the preparatory process becomes readily available. The main clause can then refer to an event that forms part of that preparatory activity:

(190') When the car started, it was *me* who turned the ignition key.

Similarly, it is hard to find an interpretation for (191).

(191) ?When Tia recited a poem, John played the piano.

If one is only trying to relay a purely temporal relation between the two events, (the activity of *playing the piano* occurred sometime during the *reciting of the poem*) then it is definitely uncooperative to use *when* (rather than *while*, for example). First of all, *when* conjures up the consequences of *reciting a poem* as part of its temporal referent. Secondly, *John play the piano* has to be situated as a functional part or as a consequence of *Tia reciting the poem*. For neither possibility does general world knowledge provide any obvious support. This does not mean that a culminated process and a process cannot be combined by means of a *when*-clause, only that world knowledge does not make such a connection a plausible one for (191). Such

an interpretation is plausible, however, for (192), which is structurally similar to (191) in that it also has a culminated process in the *when*-clause and a process expression in the main clause:

(192) When John wrote the letter, the committee acted swiftly.

Finally, a *when*-clause containing a process expression suggests that the process has a culmination and consequences associated with it, the main clause again being a functional part of the preparation leading up to this culmination point, or being part of the consequences. This makes it hard to find an interpretation for a sentence like (193):

(193) ?When John walked in the park, he lost his key.

If the referent set up by the *when*-clause was just the process of *walking*, then the main clause culmination could be situated somewhere within that process without great difficulty. However, the use of the *when*-clause suggests that the process of *walking in the park* has a culmination and consequences associated with it, and these are hard to find. Moreover, the main clause event of *losing one's key* has to be in a consequentiality relation with the culmination point provided by the *when*-clause, either being a consequence, or playing some important part in bringing it about. Again, world knowledge does not make such an interpretation easy to come by. If the expression of such a contingent relation is *not* intended then a progressive *when*-clause can be used:

(194) When John was walking in the park, he lost his key.

In the cases discussed so far, main clauses were always of the event variety. The difference with stative main clauses is that the latter seem to act as a kind of background against which the *when*-clause is to be situated; no contingency link is established between the two states of affairs. This holds true for ordinary stative expressions as well as for consequent, progressive and habitual states:

(195) When they built that bridge
 ...I was still a young lad.
 ...my grandfather had been dead for several years.
 ...my aunt was having an affair with the milkman.
 ...my father used to play squash.

The absence of a consequentiality relation between *when*-clauses and stative main clauses can, again, be explained in terms of the temporal referent they establish. But first, a word is in order about the way stative expressions describe states of affairs.

It is in the nature of states that they are identical at every point at which they hold. This explains, for example, the ease with which they occur with punctual time expressions and the

way in which a state surrounds the punctual expression (cf. also chapter 7). Thus, in


(196) When I came in, Harry was in a good mood.

we know that Harry was in a good mood at the point at which I came in. He may have been in a good mood before and after, but neither of these states of affairs are entailed by (196).

We can therefore think of a state as a punctual entity as in (197); the arrows indicate that the state may extend forwards and backwards in time.

(197) $\langle \text{-----O-----} \rangle$
J be ill

In combination with a *when*-clause, such a stative point can be placed anywhere along the nucleus associated with the *when*-clause, for example immediately after the culmination, as in (198):

(198) 

However, since a situation can extend backwards in time, it can go across the culmination point given by the nucleus of the *when*-clause, which means that the state cannot have been caused by that culmination point. Whether or not this really is the case is largely dependent on world knowledge and may often remain undetermined. Consider the examples in (199) (cf. Smith 1983: 487):

(199) When Harry broke that vase, Sue was in a good mood.
When Harry broke that vase, Sue was in an extremely bad mood.
When Harry broke the vase, Sue was already 3 months pregnant.

The stative expressions can hold before and up to the point where Harry breaks the vase; they can hold before that point and extend beyond it; or they can start just after (and because of) the culmination point referred to in the *when*-clause. For some states, such an inchoative reading is easier to come by, as in (200):

(200) When Harry came in, I knew the answer.

To indicate that the state held for some time before that, some additional linguistic material may be added:

(200') When Harry came in, I already knew the answer.

The account of *when*-clauses outlined so far also explains the behaviour of stative expressions in the *when*-clause. These have to be turned into culminated processes and, as was discussed in chapter 5, this can be done in a number of ways. First of all, the state has to be turned into

a process, and then context has to be searched for a particular culmination point to be associated with this process. Very often, a lot of context will be needed before this can be accomplished:

- (201) (a) ?When I was unaware of the facts, I made a lot of mistakes.

The transition from process to culminated process can also be made via the point and then the culmination node. As was described in section 5.1.2, this gives the process (or its original state) an inchoative interpretation. It is a reading which is very often associated with *when*-clauses containing stative expressions (cf. Partee 1984: 262):

- (201) (b) When I knew the answer, I wrote it down.
(c) When the room was empty, the janitors came in.

In both cases, the main clause events are felt to be part of the consequences of the inchoative states described in the *when*-clause.

There are, however, sentences whose interpretation does not seem to follow the rules given here:

- (202) When I was young, Fred hit me with a shovel.

The apparent strangeness of the sentence can be repaired by adding *still* to the *when*-clause:

- (203) That accident happened when I was (still) very young.

The need to use *still* in these cases seems to suggest that - however stable and long-lasting the state of *being young* may look - by describing such a state by means of a *when*-clause it becomes a transitory state of affairs: it can be thought of as a structured event, even one with a final bound. The use of *still* has the capacity to overrule this reading.

The fact that the stative *when*-clause in (203) *can* keep its stative reading - albeit through the use of the special indicator *still* - does suggest that stative *when*-clauses do not *always* change meaning. Consider (204):

- (204) (a) When we were in New York, we had a great time.
(b) When we were in Edinburgh, it rained several times.

The *when* connector here seems to express temporal co-extension or even temporal inclusion and apparently becomes hard to distinguish from *while*. There is, nevertheless, an important difference. *While* presents a state of affairs as a temporally bounded process; the main clause is supposed to have occurred within those temporal bounds:

- (204') (a) While we were in New York, we had a great time.
(b) While we were in Edinburgh, it rained several times.

A stative *when*-clause, on the other hand, seems to suggest that at any time (or, in the case of

204b, several times) during which the state held, the main clause also held. In the case of (204) this practically amounts to stating a relation of temporal inclusion. Because of this it becomes hard to see the difference between (204) and (204').

Yet, just as we have seen before that *when* does not express a mere *after* or *before* relation, but rather seems to say something like "after (or before) *and* because of", similarly *when* with a stative clause does not just express a relation of temporal inclusion:

- (205) (a) When I last had the flu, my doctor gave me anthrophax.
 (b) ?While I last had the flu, my doctor gave me anthrophax.

What seems to happen in an example like (205a) is that the *when*-clause takes a point at which the state holds, and this point then becomes the core event in a culminated process. The main clause in (a) is part of the consequences. It is *not* part of the consequences of the whole state of being ill, but of one of the stative points turned culminated process.

If one takes such a stative point of *being ill* and turns it into a culminated process of its own, it becomes conceptually possible to refer to the preparatory process associated with this new complex entity. It is, however, hard to see how such a preparation would be different from the preparation associated with the *whole* state of *being ill*. And *that* preparation, i.e. the preparatory process leading up to the whole state of being ill, *can* be referred to, although quite a bit of context is needed to support such an interpretation:

- (206) When I was ill last time, I ate mussel stew at Maxis.

A cooperative speaker really has to disambiguate such a sentence by using a past perfect main clause, thus clearly establishing that the state of affairs described in the *when*-clause is part of the consequences of the event described in the main clause. Note, however, that this is in line with the general theory of how *when*-clauses operate, in contrast with the meaning of *while*-clauses:

- (207) (a) When we were ill last time, we had eaten mussel stew at Maxis.
 (b) *While we were ill, we had eaten mussel stew at Maxis.

To summarize, a *when*-clause can have two functions. One is to trigger a search in episodic memory for an occurrence of a state of affairs of the kind described in the subordinate clause, and to associate a complete nucleus with it. The main clause is to be evaluated with respect to this nucleus. Alternatively, a *when*-clause can describe a state which acts as a background against which the main clause is to be situated.

The account offered here clearly gives more structure to *when*-constructions than is the case in

most current accounts. Consider (208):

(208) When John was in New York, Lary left.

Bach (1981) describes the temporal semantics of (208) as follows:

there must be at least one moment of John's being in New York coincident with Lary's leaving (1981: 72)

As I have tried to show in this section, this can only be part of the account. In fact, Bach's interpretation of (208) is probably not the most natural one; a reading of (208) as *as soon as and because of* seems to be more natural.

The account of *when*-clauses offered here is fairly complex. A lot of pragmatics is needed to fully understand the meaning of this temporal connective, and implementation of these ideas in a grammar of event descriptions will depend on a suitably worked out representation formalism for general or domain specific world knowledge. Although no such theory of pragmatics exists at the moment, it is arguably important that semantic theories are designed in such a way as to specify at which point and in what way a theory about world knowledge should come into play. The implementation in chapter 8 is intended to contain a first sketch as to how this can be accomplished.

6.2.2. Other temporal connectives

It emerged from the previous section that *while*-clauses can be combined with expressions of any aspectual type but always give these expressions a process reading. This accounts for the infelicitous use of culmination expressions in *while*-clauses, unless context makes it clear what type of preparatory process one is talking about (cf. 209a), and for the iteration associated with point expressions in the same context (b):

- (209) (a) ?While the train arrived...
(b) While John tapped on the window...

When the main clause is punctual, its reference time is included in the referent set up by the *while*-clause, as is illustrated in (210):

- (210) She left while we were in the garden.
John arrived while Vance was playing the piano.

When the main clause pertains to an extended event, this event is usually temporally included in the *while*-clause event, although - as Heinamaki (1974) argues - it suffices just to have overlap between the two states of affairs:

- (211) It rained while they slept.
The sun was shining while I was outside.

Since *while*-clauses refer to the process part of a nucleus, they often occur with progressives, whose function is exactly to indicate that the process is ongoing:

- (212) He died while he was crossing the road.
I arrived while he was phoning the police.

In fact, it has been argued (see Steedman 1982) that sentences such as (213) are considered to be unacceptable by some informants:

- (213) ?While Sue played the sonata, John left the room.

Steedman suggests that the relation between *while*-clause and main clause is not one of temporal inclusion, but one of co-extension. In sentences like (212), *while* collects together all the points at which the progressive is in force and states that one of these points coincides with the point at which the main clause event occurs.

Since the intuitions about (212) and (213) are not very clearcut (Heinamaki 1974, Johnson-Laird 1976 and Ritchie 1979 all allow sentences like 213), it might be safer to accommodate both options. The functional nature of *while* can then best be described as follows:

- (214) *while*: STATE \dashrightarrow STATE
EVENT \dashrightarrow PROCESS

The rule in (214) still allows event descriptions to be combined with *while* to get the process readings of these events. The rule also allows *while* to combine with states which either keep their aspectual type or which change to event descriptions of the process variety. For the semantics of the whole sentence, it would suffice to specify that the time of subordinate and main clause either coincide or overlap. A sentence like

- (215) Harry left while John left

would be ruled out on two counts: first, *John left* is a culmination expression, so combination with *while* is ruled out. If a process interpretation is found, then an interpretation for (216) can still be blocked if we assume that the time associated with the main clause is a point, and points cannot coincide with a period or enter into an overlap relation. At the same time, Heinamaki's intuition is accounted for, since

- (217) It rained while they slept

does not require the main clause event to be temporally included in the subordinate clause event; overlap of the associated time periods suffices. Finally, Steedman's intuition will also be accounted for. In

- (218) ?While Sue played the sonata, John left the room

the punctual time entity cannot be identical to nor be in an overlap relation with the period associated with the *while*-clause event. It is felicitous, however, to assert

(219) While Sue was playing the sonata, Harry left

if we assume that stative sentences have a punctual entity as their temporal referent (as was argued in the previous section) and that the punctual main clause event coincides with one of these stative points.

This informal treatment of *while* shows the importance of using event-based ontologies in conjunction with temporal reasoning processes over periods or points - as was advocated in chapter 3. After specifying what type of expression can combine with a certain temporal connective and what aspectual category the resulting expression belongs to, a time-checker then has to verify whether the relation between the temporal entities associated with the event descriptions is the one required by the connective.

Thus, an expression like *as long as* can only combine with a process expression. Its semantics further specifies that the time period associated with the main clause has to be identical to the time period associated with the subordinate clause. This will rule out a sentence like (220);

(220) ?It exploded as long as he was sleeping.

The state of *being sleeping* was turned into a process first, thus getting temporal bounds. But the time associated with the main clause culmination expression is a point. This makes it impossible for both temporal entities to coincide.

6.2.3. Presuppositions and event descriptions

It may have been noticed that in all the examples in the section on *when*-clauses, the subordinate clauses were ordered before the main clauses. The processing of these sentences was also described as *first* involving a search in episodic memory for an occurrence of the event described in the *when*-clause, to associate a complete nucleus with this event, and only *then* to process the main clause. This processing order is meant to reflect in procedural terms the presuppositional content of *when*-clauses.

From a procedural perspective, presuppositions can be described as having the nature of a partially executed program (cf. Steedman 1977). When talking about *Harry's supervisor's oldest daughter's car*, for example, one first establishes a referent for Harry, then one for that person's supervisor, then one for *that* person's oldest daughter, etc. If this process breaks down somewhere, for example because Harry has no supervisor, then that breakdown corresponds to the presupposition that has been violated. At that point, it is sensible to abandon any further attempts to establish a referent for the whole expression.

In English, the distinction between the presupposed and the asserted part of the utterance is usually reflected in the sentence order: the presupposed information normally precedes the asserted or new information. This also holds for sentence-initial *when*-clauses. As was discussed in chapter 2, they behave rather like phrases that are used to explicitly change the topic, like *and your father* in the following example from Isard (1975):

(221) And your father, how is he?

Similarly, the novel temporal referent a *when*-clause brings into focus is presupposed to be uniquely identifiable. Following the standard procedural perspective of presuppositions as partially executed programs, memory is therefore first searched for an occurrence of the event described in the *when*-clause before proceeding to the main clause. As was described in chapter 2, Isard's (1974) program embodied a similar principle for the processing of *when*-clauses.

The reason therefore for having only examples with *when*-clauses in sentence-initial position was to ensure that the *when*-clauses would be interpreted as presupposed. The strategy of first searching memory for an occurrence of the event described in the *when*-clause before processing the main clause should then reflect the most natural interpretation for these sentences.

When-clauses *can* of course occur in sentence-final position as well. Consider (222):

- (222) When did Harry leave?
 (a) Harry left when Sue arrived.
 (b) ?When Sue arrived, Harry left.

Yet, in contexts like these the order in which subordinate and main clause are processed is not particularly relevant anymore. After asking the question in (222), the event of Harry leaving has already been located in memory. To process either (a) or (b), it will suffice just to process the *when*-clause and take that as the relative time at which Harry left. In fact, to answer (222) one could appropriately use a simple

(222) (c) When Sue arrived.

A final word is in order about the validity of the general strategy of translating the presupposed part of event descriptions into a search instruction for episodic memory before testing whatever is asserted about them. Most problematical are times and dates, as in (223):

(223) At six, Harry left.

As Miller & Johnson-Laird (1976: 428) point out, there is a problem about translating times as search procedures since they are not a very good probe with which to enter episodic memory.

They are better taken as test instructions to be applied to the event found in episodic memory. This is usually reflected in the way we structure questions. Thus in processing

(224) Did Harry arrive at six?

one first tries to locate the event of Harry's arrival. Only then can a test be carried out whether this event really occurred at the time mentioned.

It follows that the strategy people follow when processing this kind of query is essentially different from the way one could have a machine process the same queries. Indeed, it is fairly straightforward for programs to organize information with timestamps - if dates are available, that is. In such a database, a time specification could be used unproblematically as a search probe. In chapter 8 I will return to the question of whether it is, nevertheless, desirable to mimic up to a certain point the episodic structure of event memory in machines.

6.3. The temporal structure of discourse

The previous sections describe some of the mechanisms involved in the processing of expressions that contain explicit information about the temporal relations between them. In this section I will concentrate on the processing of simple linear narrative - i.e. narrative consisting of sentences without overt indication of their temporal relationship. When processing text of this type the listener, as always, tries to build a representation of the way the states of affairs talked about are related to each other, but faces the added problem that this model has to be constructed without the help of these overt temporal indicators. In this section I will try to show that the episodic nature of events is a guide for the listener as to how such an event representation can be built.

As was described in chapter 2, Partee (1984) contains a description within the framework of discourse representation theory of how an event structure can be built up for a given discourse. Of central importance in this approach is Reichenbach's notion of reference time: a past tense sentence is always interpreted with respect to a past reference time. If the sentence has simple aspect, the state of affairs it describes is interpreted as being included in the current reference time and introducing a new reference time just after the time of the last introduced event. In the case of a stative sentence, the state of affairs is taken to surround the current reference time and no update of the reference time is carried out.

It was also pointed out in chapter 2 that this approach leads to inaccuracies when dealing, for example, with a discourse as in (225):

(225) John threw a big party. He invited all his old friends.

After processing the first sentence, the reference time has been moved forward. It is with respect to this new reference time that the next simple past sentence has to be interpreted. This results in an event structure in which *he invited all his old friends* occurs *after* he threw the party.

It was suggested in chapter 2 that this problem could be overcome by taking into account the internal structure of events. Such an account should allow the event of inviting people to be part of the bigger event of throwing a party. The episodic event structure developed in the previous chapters is meant to capture exactly this. Just as was the case with *when*-clauses, the simple past sentence in (225) seems to provide a complete nucleus with respect to which the following sentence has to be interpreted. In the case of (225), the second sentence is interpreted as being part of the preparatory process associated with the throwing of the party.

In this approach, reference times do not play the same role as they do in the strictly referential accounts like Partee's or Hinrichs' discussed in chapter 2. The function of reference times is incorporated here into the nucleus structure associated with events. As was described in chapter 4, the temporal referent of an expression is a part of a nucleus - exactly which part of the nucleus is determined by the inherent meaning of the verb and of the transitions the expression underwent in the aspectual network. As a result, a tensed clause does not set up a reference time which coincides with or is divorced from the event time and to which future anaphoric reference can be made. Rather, the event describes (part of) a nucleus. It is to this nucleus structure that later tenses can anaphorically refer.

In a sense, this approach thus becomes more akin to Partee's original suggestion (1973) to let tense be anaphoric directly to events rather than to the intermediate reference times. The problems with that approach, notably in the treatment of progressives and perfects, is overcome in the approach presented here because of the more complex structure associated with events. I will illustrate this shortly.

The suggestion to do away with explicit reference times can also be found in recent work in the area of discourse representation theory. Reyle (1986) argues that discourse representation structures should be kept free from unmotivated discourse referents such as reference times. Tenses are taken to be directly anaphoric to events, and relations of precedence and overlap are defined directly between the states of affairs tensed clauses describe. These relations, in Reyle (1986) expressed in terms of accessibility relations between discourse representation structures,

can be paraphrased as follows. In the case of a simple narrative, consisting of three consecutive simple past sentences, the possible event structures are the following:

(226) (a) $e_0 < e_1 < e_2 < e_3$

(b) $e_0 < e_1$
 $< e_2 < e_3$

(c) $e_0 < e_1 < e_2$
 $< e_3$

(d) $e_0 < e_1$
 $< e_2$
 $< e_3$

The event described in the first sentence (e_1) is interpreted with respect to a point in the past (e_0) - possibly an event described in previous discourse, or a point in time which is clear from context. The next event is always interpreted as happening just after the previously introduced event, or after the one before that. This rules out a structure as in (226d):

(226) (e) $e_0 < e_1 < e_2$
 $< e_3$

After processing events e_1 and e_2 , e_3 can only be situated immediately after e_2 or immediately after e_1 ; it cannot take up position immediately after e_0 .

This rule system allows Reyle to give an account of the temporal structure of a discourse as in (227):

(227) Last year, John finally conquered the K4. The first day, he climbed to camp C. There he spent the night. Then he started on the North face. Less than 12 hours later, he arrived at the top. He was celebrated as a hero.

The temporal relations between the events described in this discourse can be represented as follows:

(227') $e_0 < \text{J conquered the K4}$ $< \text{he was celebrated}$
 $< \text{he climbed to camp C}$ $< \text{he spent the night}$ $< \text{he started on the N-face}$ $< \text{he arrived 12 hrs later}$

It is certainly true that the structure in (227') is allowed by the rule system of Reyle; it is less clear by what mechanisms it is arrived at. Webber (1987), however, offers useful insights with respect to this matter. Moreover, the events of climbing, sleeping, starting on the North face and arriving at the top are not just events that have no temporal relation with respect to the event of conquering the K4 - as seems to be suggested by the representation in (227'). Rather,

they all form functional parts of that event, something which Reyle's rules do not capture. I will return to both these points shortly.

In Reyle's machinery, states are assumed to overlap with the last mentioned event. Consider (228):

- (228) John left the house. He was feeling great. It was a beautiful summer day. The lake nearby was glittering in the sun.

As was discussed in chapter 2, an account of the temporal structure of this discourse has to ensure that the states do not pairwise overlap, resulting in a structure as in (228') (where O indicates overlap):

- (228') e1 O s1 O s2 O s3

To avoid this problem, Hinrichs (1986) suggested using a reference time: each state overlaps with the reference time which does not get updated. This results in a structure where all of the consecutive states have at least one point in common - which is exactly the kind of event structure we want for (228). Reyle's rules however have exactly the same effect without the use of reference times: in line with the idea described before that states function as a kind of background against which events can occur, each state is assumed to overlap with the last mentioned *event*. This means that in the case of (228) each state will overlap with the event of *John leaving the house* - exactly as we want it.

To summarize, Reyle (1986) offers an attempt to describe the temporal structure of discourse (and in particular the forward movement of narrative time) in terms of direct relationships between the events and states talked about in the discourse, rather than through the use of intermediate reference times. He does not take into account the internal structure of events. As a consequence, some of the resulting event structures are somewhat underspecified. Reyle also does not make explicit the strategies people use when building these event representations; his rules are only meant to define well-formed representations.

The most systematic account to date of the strategies people use to build structured event representations when processing simple narrative can be found in Webber (1987). Although she makes use of explicit reference times, her results can be carried over into the framework we are developing here.

Webber introduces the notion of temporal focus to refer to that node in the event representation under construction which is most salient for the interpretation of the next utterance. The most

basic strategy in processing an unmarked narrative is that of interpreting an event description anaphorically with respect to the current temporal focus, unless there are clear semantic or pragmatic reasons to assume that this is not the case. In terms of the nucleus representation used here, this means that after processing a clause, the nucleus associated with that clause becomes the temporal focus. The nucleus associated with the next clause will have to be situated somewhere along this nucleus, its exact location being determined by general world knowledge as well as by specific knowledge about the discourse. A few examples will clarify this principle.

- (229) (a) John walked into the room. He asked for the reports.
 (b) John walked into the room. He walked slowly but with confidence.
 (c) John walked into the room. He was smiling.
 (d) John walked into the room. He had asked for the reports.

We assume that a previously established temporal focus exists when the listener encounters the first of these sentences. (As Webber remarks, listeners are very good at choosing an arbitrary temporal focus when they start processing a story.) The first sentence, a culminated process expression, describes a whole nucleus. This becomes the temporal focus with respect to which the second clause will be processed. In the case of (229a), the nucleus associated with the second event description will be situated immediately after the first nucleus. The second nucleus becomes the most salient entity for subsequent anaphoric event reference.

In the case of (b), semantic knowledge tells us that the second clause is not to be situated after the nucleus associated with the first event description, but rather as a part of it. In the case of (c), the second clause gives a stative point which can be situated as immediately following the event of the first clause. As was described in the previous section, it is in the nature of stative points that they can extend forwards and backwards in time, thus accounting for the interpretation of overlap between the states of affairs described in these two sentences. In keeping with the backgrounding nature of states as exemplified in Reyle's rule for stative overlap, the state does not become the new temporal focus.

In (d), finally, the second clause only has the consequential part of the nucleus associated with it. The nucleus associated with the first event description has to be situated within that consequential part of the second nucleus. As a result, the core event of *asking for the reports* becomes temporally located *before* the event of *walking into the room*.

In (a), a new temporal focus is created with the processing of the second sentence. However, as Reyle has shown, the previously mentioned event also remains a plausible candidate for

subsequent anaphoric reference. In line with a suggestion made by Webber, we will say the old temporal focus was stacked. It can be popped if at a later stage the current temporal focus is considered unsuitable as an antecedent against which to resolve a tensed expression. This principle can be used to account for an example like (230):

- (230) All of a sudden, lightning struck. John switched off the television. Pete closed the windows.

After the processing of the first two sentences in (230), two temporal foci are in play, one associated with John's switching off the lights, the other one - on the stack - of the lightning. When interpreting the third event description, the current temporal focus may be discarded as a possible nucleus against which to situate that event and the other focus is popped off the stack.

This account differs from Webber's in that, according to Webber (1987), sentences describing events using perfect auxiliaries also create a new temporal focus. As evidence, she offers examples like the following:

- (231) (a) John went to visit Mary. He had bought her some flowers.
They failed to cheer her up.
(b) John went to visit Mary. He had bought her some flowers.
He picked 5 red roses and 4 white ones. Unfortunately,
they failed to cheer her up.

It is claimed that the perfect in the second sentence sets up a new temporal focus which is discarded on pragmatic grounds for the interpretation of the third sentence in (231a), but which is used for the interpretation of the third sentence in (b). For the interpretation of the fourth sentence in (b), the temporal focus associated with the event description *John went to visit Mary* is popped off the stack.

A few remarks are in order about this analysis. First, one has to be careful when discussing small stretches of discourse like this that the first sentence is not interpreted as a kind of "title" or summary of the whole story - in which case all the following event descriptions will be interpreted with respect to that opening line. This problem can be overcome by using a sentence which clearly indicates one is situated in the middle of the story:

- (232) At last, John reached Mary's house. He had bought her some nice flowers. He picked three red ones and four white ones.

Secondly, British English speakers do not agree that one *can* felicitously refer back to the buying event of the second sentence in (231) and (232) using a simple past in the third sentence. Most would prefer a perfect, as in (232'):

- (232') At last, John reached Mary's house. He had bought her some nice flowers. He had picked three red ones and four white ones. Unfortunately, they failed to cheer her up.

This seems to indicate that for Webber's phenomenon a special account is needed for the simple past, acknowledging that in American English it is taking over some of the functions of the perfect, rather than attributing to the perfect the capacity of setting up a new temporal focus.

The mechanisms described here are clearly more powerful than Reyle's, in that an event description can be interpreted relative to another event description even if they are separated by more than one intervening clause. It is not clear whether there is a limit on the number of intervening clauses before a node in the event structure becomes inaccessible for anaphoric reference. There certainly is a limit on how far back a tense morpheme can refer, but Webber's model aims to be a more general theory of event anaphora, also accounting, for example, for subsequent anaphoric reference by means of a definite event description, as in (233):

- (233) Last year, John renovated his kitchen. He installed a microwave and a pasta machine and then invited all his friends for a kitchen warming party. *Before he did the renovations*, however, he made sure his banker was willing to put up the money.

The use of episodic event structures achieves a somewhat greater generality in the specification of the various heuristics involved in the construction of an event representation than is possible by using intermediate reference times. Webber postulates two heuristics for the processing of embedded discourse. The first one comes into play when the current temporal focus is rejected through semantic or pragmatic inconsistency. She illustrates this principle by means of the example given before:

- (234) John went to visit Mary. He had bought her some flowers. He picked 5 red roses and 4 white ones. Unfortunately, they failed to cheer her up.

In Webber's account, there is only one temporal focus after the first two sentences have been processed. This is due to the fact that she uses reference times as the temporal focus, and the simple past and the past perfect in (234) are interpreted with respect to the same reference time. Disregarding for the moment what I said before about the use of the simple past in this discourse, the third sentence cannot be interpreted with respect to that temporal focus. A new one has to be set up, coinciding this time with the *event* time associated with the previous event description. This is what is captured in Webber's first embedded discourse heuristic. This means that tenses can be directly anaphoric both to reference times as well as to event

times. As was shown before, there is no need for this special embedded discourse heuristic in the approach presented here, since temporal foci are automatically equated with the nuclei associated with tensed clauses.

Webber's second embedded discourse heuristic is designed to account for discourses like (235):

- (235) Oh, I ran into John yesterday. He spent five weeks in hospital for what was assumed to be a simple operation. He had to undergo various blood tests and a complete encephalo-scan. He was still feeling weak.

In (235), there is no suitable temporal focus to interpret the past tense in the second sentence. The listener is then assumed to set up a new node in the event structure, just as s/he does at the start of a narrative, stacking the current temporal focus. Consecutive sentences are then interpreted with respect to the temporal foci associated with the embedded narrative. When this strategy breaks down, the stacked temporal focus is used - as is the case in the last sentence in (235), marking the end of the embedded narrative and the continuation of the main story.

In Webber's current account, there is a potential problem with the division of labour between the two embedded discourse heuristics. Although Webber does not say this explicitly, the formulation of her strategies will have to be supplemented with a rule for the forward movement of time in a narrative, and this is not entirely unproblematic. Consider again the example discussed before with respect to Reyle's account:

- (236) Last year, John finally conquered the K4. The first day, he climbed to camp C. There he spent the night. Then he started on the North face. Less than 12 hours later, he arrived at the top. He was celebrated as a hero.

The second sentence can be interpreted according to the general focus maintenance rule. If, however, we combine this general rule with an automatic update in time, then the resulting event structure will indicate a temporal progression of all the events mentioned in (236), rather than establishing the subsumption relation that seems to be required. It could be argued that in cases like this the second sentence should *not* be interpreted with respect to the current temporal focus and that one of the embedded discourse heuristics should come into play. However, the first embedded discourse heuristic cannot apply, since no appropriate previously introduced event is available that is different from the current reference time. And the second discourse heuristic would allow any time in the past to be invoked as the temporal focus with respect to which the embedded discourse is to be interpreted, which does not give the desired result either.

There is also another problem attached to the general strategy of assuming an independent principle stipulating that a reference time autonomously advances during a narrative - the strategy adopted by Partee (1984), Hinrichs (1986) and Dowty (1986). Such a stipulation not only creates problems for those parts of the narrative where the reference time does *not* seem to advance, as was noted before, but also still leaves the *amount* by which it advances to be determined by context. The concept of a nucleus allows us both to explain the fact of the advance and its extent. We only need to assume that a main clause event such as *Harry walked into the room* is interpreted as an entire nucleus, complete with consequent state. By definition, the consequent state includes whatever other events were contingent upon Harry walking in, including whatever he did next. Provided the context or the hearer's assumptions about the world support the idea that the subsequent main clause identifies this next contingent event, the nucleus will provide the temporal referent for that main clause.

To summarize, if tenses are taken to be directly anaphoric to the nuclei associated with events, Webber's first embedded discourse heuristic becomes superfluous, while still allowing for a proper treatment of discourses like (236) - including a notion of temporal movement. The second embedded discourse heuristic can then be kept to account for really embedded narrative which is unconnected to the main story line, as was illustrated in (235). Note, however, that (235) is *not* an entirely unmarked narrative. It is the expression *five weeks* which blocks inclusion of that event into the nucleus associated with the event description *I ran into John yesterday*. And the popping of the temporal focus for the interpretation of the last sentence in (235) is probably done *after* that sentence was processed and the listener realized the discourse was finished.

Finally, forward movement of time in narrative is a consequence of situating an event in the consequential part of the nucleus associated with the previous event description, and taking this new event as the new temporal focus. As a result, time does not move forward in a narrative with stative clauses, since the stative point that they add to the overall event structure of the discourse cannot become a new temporal focus.

Letting the forward movement of time follow from what is essentially a non-temporal property of the nuclei also allows for an account of sentences like (237):

(237) John fell. Mary pushed him.

Although in narrative the most likely place for an event to attach itself to the current temporal focus is among its consequences, the preparatory period leading up to the event is also

available for subsequent anaphoric reference. This is what happens in (237), where Mary's pushing John will be taken to be part of the preparatory process leading up to John's fall. Time seems to be moving backward here, but no exceptions to any rules have to be stated.

6.4. Conclusion

Where in previous chapters the idea was developed that the concept of a nucleus is what is involved in the usage of certain temporal and aspectual categories, the present chapter examined how this concept can be used to give an account of the overall temporal structure of discourse. It was argued that the nucleus is the entity which *when*-clauses introduce into the discourse and to which the Reichenbachian "reference time" implicit in the tenses actually refers.

It was shown that a theory of *when*-clauses based on an ontology that uses nuclei as its basic entities allows for an account of the apparent ambiguities of *when* while still maintaining that *when* has a single sense. The argument that these apparent ambiguities should all be left to pragmatics was also discarded: it was shown that there must be *some* element of the sense-meaning of *when* which distinguishes those examples from perfectly felicitous parallel utterances using other temporal connectors (like *while* or *as long as*).

The organization of events under the consequentiality relation implied in this ontology can also be used to give an account of the structure of simple linear narrative. The phenomenon of forward movement of time can be seen as a consequence of this way of organizing events into a structured representation, rather than as an organizing principle itself.

Chapter 7

The aspectual classification of event descriptions

7.1. Introduction

In the previous chapters, it was shown how the ontology embodied in a dynamic aspectual classification can be used to give an account of a great number of temporal and aspectual phenomena in English. However, a number of puzzles remain to be explained.

To begin with, it was observed that the aspectual network is a classification of sentence meanings rather than verb meanings. Yet, when discussing examples I have always assumed that *verbs* belong to some "basic" category. This may seem contradictory, and some clarification is certainly in order.

Moreover, as was pointed out in previous chapters, an interpretation can be found for almost any combination of a verb or verbal expression with, for example, a certain adverbial. This makes it hard to see what would constitute a "basic" context to decide what aspectual category the expression "typically" belongs to.

Also, in the past sections I have been using tenseless sentences to describe parts of the nucleus. On the other hand, I have stressed the fact that tense *does* play a role in facilitating certain transitions in the aspectual network. Since tenseless sentences play an increasingly important role in certain tense logics (e.g. Richards 1986, Vuyst 1983, Vlach 1981a), it is important that the status of tenseless clauses be clarified from an aspectual point of view.

Finally, there is Dowty's claim (1986) that a syntactic approach to aspectual classification misses the point and should be replaced by a semantic one. This observation is an important one, and has important repercussions for the kind of approach advocated here and for the implementation of these ideas in chapter 8.

7.2. Aspectual categories and tenselessness

In chapter 4 I stressed the fact that an aspectual classification should not be thought of as a classification of *verbs* (as Vendler seems to suggest) but one of *sentences* (or sentence meanings). At the same time, examples were given where *play* or *run* were said to be process

expressions, and *play the sonata* or *run a mile* were considered to be culminated processes. This seems to suggest that the categories in the aspectual network do not just label the aspectual classes of sentences, but also of smaller units, such as verbs or verb phrases. This is indeed the case; the network can be used to classify *all* these linguistic units. Thus in

(238) John was walking to the theatre.

walk is a process, *walk to the theatre* a culminated process, and the whole sentence a progressive state.

It is important to realize, however, that in all these cases one is actually classifying propositions: when talking about the aspectual category of a verb, one is really talking about the temporal characteristics of a "basic proposition" (Lys & Mommer 1986) which contains this verb, i.e. a simple clause from which everything is excluded which we know might change the aspectual type of the expression.

From what has gone before, it is fairly easy to define the characteristics of such a proposition. To begin with, the sentence should be stated in the simple past. The simple aspect is chosen because we know that progressive and perfect auxiliaries change the aspectual nature of the sentence. The past tense is chosen because, as was argued in chapter 1, English is a 2-tense language; as a consequence, non-past tenses allow a greater variety of interpretations thereby changing the temporal profile of the expression: a non-reporter's present tense, for example, changes events into habitual states. *Will*-futures are often described as modal states and are therefore not good candidates to build a basic proposition with.

The subject of a basic proposition should be syntactically and semantically singular. Similarly, the object should be a singular count noun, and it should only be present in the case of a necessarily transitive verb (but cf. *infra* for a caveat about this). As a result, the statement that *run* is basically a process verb is really a shorthand for the statement that a basic proposition involving this verb, for example *John ran*, is typically a process expression. These criteria for what constitutes a basic proposition, defined along similar lines in Lys & Mommer (1986), should also be used when classifying more complex expressions - at least as long as the criteria are applicable. Thus, to determine the aspectual category of an expression like *eat a McDonald's hamburger in less than 40 seconds* we try to build as basic a clause as possible following the above rules, i.e. use the simple past and choose a singular subject; a direct object is already present, so that rule does not apply. This might result, for example, in (239):

(239) My brother ate a McDonald's hamburger in less than 40 seconds

Since (239) is a proposition of the culminated process variety, the expression *eat a hamburger in less than 40 seconds* will also be referred to as a culminated process expression.

In the next section, I will discuss how the aspectual category of a proposition (either basic or not) can be decided upon. But it should be clear that the classification is always one of *propositions*. And ultimately, when deciding on the temporal structure of discourse, it is propositions conveyed by sentences uttered *in context* that are given an aspectual classification.

When discussing the changes of category an expression undergoes, I have assumed the habit of talking about the aspectual class of the tenseless verb, verb phrase or other linguistic unit, and adding tense in the last step when giving the sentence its final aspectual label. In view of recent developments in tense logics some explanation about this is called for. In Richards (1982, 1986) a tenseless sentence is not just an abstract entity that tense and aspectual categories operate over, but a linguistic category which occurs in contexts such as (240):

- (240) (Bill demanded that) Sam leave.
(I insist that) Mary have finished by 3 o'clock.

In view of this, tenseless verb phrases like *build a palace* or *run a mile* cannot be said to be culminated processes. Consider:

- (241) (a) The king demanded that we build him a palace.
(b) The doctor recommended that Max run a mile.
(c) Her manager suggested that Mary run the mile rather than the marathon.

Given the right context, the tenseless expressions in (241) could be describing the culminated process, the process itself, the culmination point at which the process finishes, the inchoative culmination of starting the named process, or an habitual state. If we accept the idea that tense is an operator over tenseless sentences (as in 242a), then it is apparently only after the application of the tense operator that the sentence becomes a culminated process (as in 242b):

- (242) (a) PAST(John build a house)
(b) John built a house.

It could be concluded from this that tense fulfils the function of disambiguating the aspectual character of sentences which would otherwise be aspectually ambiguous. Yet, I will continue the practice of talking about, for example, the tenseless expression *build a house* as a culminated process. One reason for this lies in the way the imperfective paradox was accounted for. To illustrate this, let us assume that in an account with tense and aspect operators (243a) would be represented as in (b):

- (243) (a) John was building a house.
 (b) PAST (PROG (John build a house))

In our account, the tenseless *John build a house* is classified as a culminated process; since the progressive can only apply to a process, a transition has to be made which strips off the culmination point. It is this transition which forms the core of our account of the imperfective paradox. If, however, the tenseless sentence in (243b) is considered to be aspectually ambiguous, then the progressive could be operating over the process meaning of the tenseless clause without any transition being forced. This way one seems to lose some grip on accounting for the change in category the progressive forces, and consequently for the imperfective use of the progressive.

The same is true for a culmination used in the progressive:

- (244) (a) John was reaching the top.
 (b) PAST (PROG (John reach the top))

By classifying the tenseless sentence *John reach the top* as a culmination, it becomes possible to give an account of the transitions it undergoes before it combines with the progressive. This then explains why (a) describes a preparatory process leading up to but not necessarily reaching the culmination. If the tenseless sentence in (244b) is considered to be aspectually ambiguous and possibly a process already, it becomes less clear how such an account would be possible.

If one wants to make use of tenseless propositions in one's logic and maintain that any such tenseless clause really is aspectually ambiguous, then it becomes necessary to specify what exactly the relations are between its different aspectual readings. This will amount to assuming a basic reading and specifying how the other interpretations of the tenseless expression are related to it - which is exactly what the aspectual network approach is trying to capture. In other words, it is correct to assume that tenseless sentences cannot be assigned to any particular aspectual category, since they can only be assigned such a category in context. But what is needed to complete such an account is some machinery which explains the relations between all these readings, and this machinery will be of the same complexity as the aspectual network proposed here.

The use of tenseless sentences in the contexts proposed by Richards also clarifies a sometimes ill-understood point about the functional nature of aspectual adverbials as discussed in chapter 5. There it was said that only the *process* reading of, for example, *arrive on time* can be combined with a *for*-adverbial, and that this process reading will most probably have an iterative

interpretation:

(245) For several days, Mike arrived on time.

It is sometimes ventured that *arrive on time* does not have such a process reading on its own, and that the process reading comes about *because* of the combination with a certain aspectual adverbial. Hence, the *for*-adverbial does not *combine* with the (iterative) process interpretation of the expression, but *creates* it. The contexts suggested by Richards for establishing tenseless clauses do show, however, that the tenseless culmination expression *arrive on time* can have the iterative reading:

(246) Max' boss insisted that he arrive on time

7.3. Diagnostic tests for the categories

When the principles of aspectual classification were introduced in chapter 4, it was stressed that such a taxonomy should be seen as pertaining to *linguistic* categories. In the previous section, it was argued that it makes sense to think of the network transitions as starting off from the basic category of the *verb*. It follows from these two claims that what is needed as a starting point is an aspectual classification of *verbs* (or the basic propositions they occur in) based on *linguistic* tests such as co-occurrence possibilities of the verb with certain adverbial expressions or with progressive and perfect auxiliaries.

This may seem to be an impossible enterprise. Indeed, the network was set up in chapter 4 after the observation that a verb can occur as almost any aspectual category, because even for strange co-occurrences of, for example, verb and adverbial as in (247), an interpretation is still possible:

(247) John ran in less than 4 minutes today.

If it is true that there is little or no restriction on the type of adverbial a verb like *run* can combine with, it seems impossible to use this sort of test as a diagnostic to determine the verb's basic aspectual category.

Nevertheless, there is a clear difference in acceptability or ease of interpretation between, for example, (248a) and (b):

- (248) (a) These animals are being very hungry.
(b) These animals are suffering from helmiatiasis.

A theory of aspectual classification will have to explain why there is such a difference. Also, a sentence like (249a) is perfectly understandable, but only as involving a repeated activity. No

such "re-interpretation" is needed for (b):

- (249) (a) He kicked her for a while.
(b) He ran for a while.

These "re-interpretations" - e.g. a process getting an inchoative reading in certain environments, culminations being stripped off or points being iterated - obviously coincide with the transitions described in the network. Because of this, the diagnostic tests I propose will reflect the functional nature of the expressions discussed in previous chapters.

Consider the behaviour of a *for*-adverbial: it can only combine with a process expression, which means stripping off the culmination point from a culminated process, or giving an iterated interpretation to a point expression. In terms of the diagnostic tests, this means that if a verb combines easily with a *for*-adverbial, it should be classified as a process verb; if a verb describes an "incomplete" event in that context, it is basically a culminated process expression; and if it gets an iterated reading, the verb should be categorized as an atomic event.

This seems to suggest that, to make sure the functional accounts offered in the previous chapter are correct, verbs have to be assigned the appropriate aspectual category first; but to establish the appropriate aspectual category for a verb, its behaviour vis-à-vis the aspectual functions has to be examined. This argument may look circular, but is not viciously so. It will be shown that a small number of tests (in fact, only three) suffice to distinguish the four event-types. Once an expression is given a category label by means of these tests, it should behave consistently as a member of that category with respect to *all* the suggested aspectual functions.

Of course, many more tests have been suggested in the literature to distinguish between Vendlerian categories - many more than the three that will be singled out here. Since tests like these should be thought of as observed facts about English for which the aspectual network and its underlying mechanisms constitute an explanation, I will discuss some of those other tests as well (cf. Dahl 1981: 85-86 for a similar view on diagnostic tests). This is also the reason why some of the existing diagnostic tests will not be discussed here. Co-occurrence restrictions of a verb with an adverb like *deliberately* does not tell us anything about the temporal profile of the event (cf. Dowty 1979: 184). Tests like these are usually designed for classifications that are intended to capture distinctions to be used in a general theory of action. They will be left out of consideration here.

In what follows, I will first separate stative expressions from event verbs, digressing a bit

further into the nature of statives. I will then deal with events, giving the diagnostic tests and comparing the tests as well as the final classification with some of the most influential existing classifications.

7.3.1. Stative expressions

From the literature on aspectual classification, two tests emerge that can be used to distinguish stative verbs from other types of expressions. On the one hand, it is often claimed that states of affairs described by stative verbs do not require input of energy to keep going on, whereas other states of affairs do. As was argued in the section on the progressive, this reduces the aspectual classification to an ontological one, whereas what we want is a classification of linguistic material.

The second criterion most often found is that stative verbs cannot occur in the progressive. Vendler (1967) used this criterion to single out achievements (culminations) as well as stative verbs. I have already discussed the possibility of combining culminations with the progressive auxiliary, so it seems then that the progressive test would indeed just single out stative verbs:

- (250) (a) *John is knowing the answer.
(b) *Tomorrow, the students are wanting their results.

The problem with this test is, as always, that there *are* contexts where stative verbs *can* occur with the progressive auxiliary. In fact, these contexts are not hard to find.

- (251) (a) John is knowing more and more about thermodynamics.
(b) I've been wanting an Apple IIe for years.

Nevertheless, I want to argue that the intuition underlying Vendler's observation is correct. The right way of describing the observation seems to be, however, that stative verbs do not *need* a progressive auxiliary in contexts where other verbs do. Take, for example, the state of affairs where you see a man walking in the park and you want to say something about him. In this situation, it would be impossible to use a simple present, since the sentence would then have to be interpreted as describing an habitual state of affairs:

- (252) ?The man who walks over there (is president of GM).

What is needed to describe the state of affairs is a progressive, as in (253):

- (253) The man who is walking over there (is president of GM).

Stative verbs, however, do not take a progressive in this context:

- (254) That man *is* president of GM.
 That music *sounds* like Mozart.
 What you *see* here is one of my granny's teeth.

This simple test allows for a fairly clear delineation of stative verbs, some of which are given in (255):

- (255) stative verbs:

<i>know</i>	<i>think</i>	<i>wonder</i>
<i>suppose</i>	<i>hear</i>	<i>regret</i>
<i>see</i>	<i>be tall</i>	<i>love</i>
<i>imply</i>	<i>doubt</i>	<i>have four legs</i>
<i>involve</i>	<i>want</i>	<i>be a mammal</i>

They can be further subdivided (as in Quirk e.a. 1985:201-203), but those subdivisions have no influence on the expression of temporal relations. As always, there still remain borderline cases, such as *live*: it is hard to decide whether (256a) is a simple present stative verb (describing the state of living somewhere) or a simple present process verb (describing the habitual state of living somewhere).

- (256) (a) John lives in London.

Likewise, it is hard to decide whether (b) is an ongoing process or a state turned into an ongoing process.

- (256) (b) John is living in London.

The main problem with the co-occurrence test of verbal expressions with the progressive auxiliary lies in the fact that in the aspectual network states form a somewhat more complex group than in more traditional accounts, comprising also progressives, habituels and perfects. For these, the compatibility test with the progressive auxiliary does not work too well. However, a number of other linguistic environments can be singled out to test for stativity.

The most important of these is the accessibility test (cf. Vuyst 1983) as described in section 5.2: when a stative expression is combined with a punctual reference time, this reference point can be temporally situated within the state:

- (257) When I came in, Harry was ill.
 When I first met him, John was extremely happy.

In (258), no overlap relation is possible; none of these expressions can be classified as statives:

- (258) When I came in, Fred told me everything.
 When he won the money, he built a house.

Note that the overlap relation need not be the only possible interpretation. In (259), for

example, an inchoative interpretation is even more likely:

- (259) When I came in, Fred knew the answer.

Yet, even in (259) the overlap relation *is* a possibility, which is enough for *know the answer* to be classified as basically stative. The overlap relation can be brought out even more clearly by adding *already*, as in (260):

- (260) When I came in, Fred *already* knew the answer.
When the doctor arrived, Sue was *already* in bed.

In fact, Vlach (1981:68) proposes compatibility with *already* as a test for stativity.

As was shown in chapter 5, the accessibility test can be used to demonstrate the stative nature of progressives:

- (261) When Sue arrived, Harry was working in the garden.
When he won the money, he was building a house.

Compatibility with *already* shows equally clearly the stative character of progressive expressions:

- (262) Harry is *already* building a house.
Sue is *already* phoning the police.

With these tests, habituals can also be shown to behave like statives in English. Consider (263):

- (263) When I last saw Harry, he took two lumps of sugar in
his tea.

There is a reading for this sentence where *take two lumps of sugar* overlaps with the event described in the *when*-clause, but only if that expression is taken to be the description of a habit. The same holds for examples like (264):

- (264) (a) When I met Richard, he sold 2 cars a day.
(b) When I first met Robert, he seldom succeeded in selling any of his products.

And again, habituals can also combine with *already* in a straightforward way:

- (265) (a) He *already* takes sugar in his coffee.
(b) When I met Richard, he *already* sold 5 cars a day.

I use the rather vague term "habituals" to include what are sometimes called frequentative, dispositional, normal or customary states (cf. Lyons 1977: 716). For present purposes nothing important follows from not making any more fine-grained distinctions. The temporal profile of habituals *is* very different, however, from that of iterated processes. Consider (266):

- (266) When I came in, Tina played the sonata several times.

The state of affairs of *playing the sonata several times* cannot overlap the point described by

the *when*-clause. It follows that *played the sonata several times* is not a stative expression, but an event expression (viz. of the process variety).

The fact that constructions with frequentative expressions like *usually*, *often*, *seldom* and even *never* turn sentences into habitual states should not mislead one into thinking that negative sentences are also automatically stative. Consider:

- (267) (a) When I came in, Harry didn't know the answer.
 At 6, she was not asleep.
 (b) When I talked to him, he didn't tell me anything.
 When he won the lottery, he didn't buy a car.

The (a)-examples seem to allow an interpretation where the negated state overlaps with the punctual expression in the *when*-clause or the adverbials. No such interpretation is possible for the (b)-examples. As was discussed briefly in chapter 5, negation does not change the aspectual character of states, but turns event-descriptions into processes.

Finally, the tests offered here can also be used to show that perfects are stative: they allow overlap of the state with a punctual reference time (as in 268a), and allow combination with *already* (as illustrated in 268b):

- (268) (a) John had left when I arrived.
 (b) Sue has already finished her supper.

To summarize, of the tests suggested in this section, the co-occurrence test with progressives is problematic, since it can only be used to test the stativity of verbs and not of other expressions. The test with *already* is unreliable for certain dialects of English. Consider:

- (269) I already wrote a paper.
 I already ate lunch.

Especially in American English, where perfects are being replaced by simple forms, expressions like (269) are judged to be acceptable. It could be argued that this means that, in American English at least, *I wrote a paper* can be a stative description of the consequences that hold after the writing of the paper. I do not think this warrants the classification of this expression as stative; it seems, rather, that the combination with "already" *forces* a stative reading which the expression does not have in other contexts. Even in American English, the simple past main clause in (270) cannot refer to the consequent state of having had lunch:

- (270) When Harry arrived, I ate lunch.

In other words, the clause *I ate lunch* fails the accessibility test, even in dialects that accept

(269). It follows that the most accurate diagnostic to test for stativity is the accessibility test with punctual temporal expressions.

7.3.2. Event expressions

Punctual adverbials can also be used to single out atomic events since only they can be described as occurring at a single moment in time; other events will get an inchoative reading, whereby the punctual adverbial refers to the starting point of the structured event.

- (271) (a) At that moment, he *blinked*.
 Just as the curtain opened, he *hiccoug*hed.
 (b) ?At that moment, my sister *played* the piano.
 ?At that point, he *wrote* on the blackboard.
 (c) At that moment, John *recognized* him.
 At 6 in the morning, the plane *landed*.
 (d) ?At that moment, the enemy *destroyed the city*.
 ?At seven o'clock, he *delivered a sermon*.

Only the (a) examples (*blink*, *hiccoug*h) and the (c)-examples (*recognize*, *land*) are atomic. The verbs in the (b) and (d) examples describe extended events.

A verb is labelled as having consequences if the basic meaning of that verb includes a reference to a change of state at which the consequences of that event start holding. Since these consequences can be referred to most easily by means of a perfect, the ease of co-occurrence with a perfect auxiliary will serve as a discriminatory test.

- (272) (a) ?He has *knocked* on the door.
 ?She has *blinked*.
 (b) ?He has *worked* in the garden.
 ?He has *written* letters.
 (c) He has *left*.
 The train has *arrived*.
 (d) The city has *erected* a statue in honour of Mario Prizzi.
 The ice-cube has *melted*.

Only the (c)-examples (*leave*, *arrive*) and the (d)-examples (*erect*, *melt*) can be classified as having consequences.

These two tests suffice to distinguish between the four types of events:

(273) culminations			culminated processes	
<i>leave</i>	<i>start</i>	<i>die</i>	<i>destroy</i>	<i>improve</i>
<i>arrive</i>	<i>stop</i>	<i>explode</i>	<i>erect</i>	<i>obliterate</i>
<i>land</i>	<i>win</i>	<i>find</i>		
<i>finish</i>	<i>end</i>	<i>recognize</i>	<i>(melt, cool, warm, darken, harden)</i>	
points			processes	
<i>knock</i>	<i>tap</i>		<i>work</i>	<i>run</i> <i>dance</i>
<i>blink</i>	<i>wink</i>		<i>write</i>	<i>swim</i> <i>eat</i>
<i>hiccup</i>	<i>nod</i>		<i>play</i>	<i>read</i>

As was to be expected, there are only very few verbs that can be classified as a culminated process; this compound category seems to need more complex expressions, like *write a book* or *play the sonata*, i.e. process expressions associated with a culmination point, the nature of which is often made explicit by means of the direct object.

If we were to formulate a general rule, saying that a process verb combined with a direct object results in a culminated process expression, then the culminated process verbs in (273) could be classified as processes: since they are necessarily transitive, they can only be used in culminated process expressions. The exceptions to this rule are minimal (*walk the dog*, *play the piano*, *run a business*). Later on in this chapter, I will come back to the possibility and usefulness of formulating such a syntactic rule.

The only verbs left in the culminated process category are verbs like *melt*, *cool* or *harden*. When they are used without a direct object, they get an ergative reading which seems to behave as a culminated process expression:

- (274) The soup cooled.
The ice melted.

Although these verbs can occur freely with a perfect auxiliary, they can also be combined easily with *for*-adverbials, without any feeling of a culmination point being stripped off:

- (275) The soup cooled for a few minutes.

This would warrant their classification as process expressions. Dowty, who discusses these verbs rather elaborately (1979: 88-90) labels them culminations on the ground that they have a goal associated with them, although according to Dowty it is a rather vague goal (*to become cooler*, rather than *to become cool*). Because these verbs describe extended events (cfr. the easy co-occurrence with a *for*-adverbial) without being associated with a clear culmination

point, it might be better to classify them as processes.

It has been argued (e.g. Dowty 1986) that no distinction should be made between (unstructured, atomic) culminations and (structured, extended) culminated processes. Dowty quite rightly points out that the difference between culminations and culminated processes does not lie in the fact that culminations usually have shorter duration, but that - given our everyday criteria for identifying the events - culminated process expressions involve recognizing distinct sub-events, which may be necessary (but are not necessarily sufficient) for the culminated process itself; culminations are not understood as consisting of such a sequence of sub-events. Nevertheless, I think the property of having sub-events (being structured) is important enough to maintain the classic distinction between culmination and culminated process - with the caveat that, indeed, the distinction is *not* one of (temporal) duration. This is also one of the reasons why the term "atomic" was chosen rather than "punctual" to label culminations and points: expressions belonging to these two aspectual categories make no reference to the internal structure or subparts of the events. And, as was discussed before, processes and culminated processes can be "compressed" into points. This also does not mean that they cease to have a temporal extension, but rather that their internal structure is no longer of importance.

The distinction between events that have consequences associated with them and those that do not is one which is quite common in the literature on aspect and related categories. Most often, terms are used such as *telic* (or bounded, perfective, terminative, resultative) for the former, and *atelic* (or unbounded, imperfective, nonconclusive) for the latter (cf. Dahl 1981). Although authors do not generally agree on their definitions for these categories, the tests they propose for distinguishing between them are quite uniform.

A first test is based on the behaviour of the progressive: (276) is atelic (or does not have consequences) since it is entailed by (276a); (277) is telic since it is not entailed by its imperfective counterpart (277a) (the culmination point was stripped off in forming 277a):

- (276) John drank beer.
- (a) John was drinking beer.
- (277) John sang the National Anthem.
- (a) John was singing the National Anthem.

Since *for*-adverbials require a process as input, and *in*-adverbials a culminated process, it follows that process verbs will be distinguishable from culminated process verbs on the basis of the ease of co-occurrence with these adverbials.

- (278) (a) John worked for a while.
 ?John worked in a few hours.
 (b) ?John built a house for a few days.
 John built a house in less than a week.

Culminated processes (as do culminations) describe a heterogeneous entity, consisting of a culmination with (possibly) preparatory process and consequences attached to them. Some tests have been suggested that bring out this heterogeneous character of culminated processes: an event can be described as *finishing* if it contains a culmination; otherwise it just stops (cf. Freed 1979):

- (279) ?John finished *writing*.
 John finished *writing a letter*.
 John stopped *writing*.

Another test based on the homogeneity/heterogeneity distinction is a co-occurrence test with *almost*: in the case of heterogeneously described events, these sentences are ambiguous - as will be clear from the (a)-examples:

- (280) (a) John almost painted a picture.
 Harry almost wrote a novel.
 (b) Jenny almost worked in the garden.
 Hilda almost played the piano.

The (b)-examples clearly state that Jenny or Hilda did not work or play. In the (a)-examples, it is left undecided whether the persons involved never engaged in the activity of painting and writing, or whether they just did not pursue it until the culmination point associated with the process.

These tests can also be used to show the telicity of non-basic expressions like *work for 2 hours* or *run a mile in less than 4 minutes*:

- (281) (a) John almost worked in the garden for 2 hours.
 (b) Harry was running a mile in less than 4 minutes

The example in (281a) exhibits the same ambiguity as was demonstrated to be present in +consequential expressions, and which was absent in the corresponding examples in (280b). And from the progressive in (281b) one cannot infer that Harry actually did run a mile in less than 4 minutes on that occasion; it could be continued *but his shoelace came undone, and he fell*. This vindicates what was argued in chapter 5 about the output categories associated with these adverbial expressions.

From tests like these, various definitions of the telic/atelic distinction can be derived (cf. Declerck 1979), although none of these definitions is very illuminating. Telic expressions are

sometimes defined as describing a state of affairs as "tending towards a goal - envisaged or realized in a perfective tense but as contingent in an imperfective tense" (Garey 1957: 106), or "being done for the sake of a goal" (Potts 1965: 65). However, the state of affairs described in Dahl's (1981: 86) sentence (282) clearly "tends towards a goal", so the sentence should be classified as telic:

(282) The submarine moved toward the North Pole.

Yet, all the tests mentioned above make it come out as atelic: combination with a *for*-adverbial is more straightforward than with an *in*-adverbial; *the submarine was moving toward the NP* entails that *the submarine moved toward the NP*. And each part of the event can be described as *moving towards the North Pole* which shows it is a homogeneous event. Only the tests with *finish* and *almost* give less clear-cut results.

And the other way round, (283), which passes all the tests for being a telic sentence, can hardly be said to describe an activity as tending towards a goal, certainly not with all the notions of intentionality the idea of a "goal" has:

(283) The rain destroyed the crops.

As was mentioned in chapter 4, it was exactly to avoid the problem of having to specify distinctions like these in terms of the presence or absence of goals or purposes, that we chose a more neutral nomenclature than is commonly used in aspect studies.

Another definition often given for telic sentences is that they describe states of affairs as "directed towards attaining a goal or limit at which the action exhausts itself and passes into something else" (Anderson 1973). Dahl's example (282) certainly belongs to this category: once the submarine reaches the North Pole the *moving towards the North Pole* exhausts itself. Yet, as we saw before, it passes all the tests of atelic sentences. And a clearly telic sentence like (284)

(284) John washed his T-shirt.

does not necessarily "exhaust" itself once the T-shirt has been washed.

A third definition for telicity comes from Dahl, who defines it as having "a definite endstate" (1975: 452). Thus, (285a) is telic since there is a particular point at which the state of affairs finished. (285b) on the other hand is atelic, since the process in (b) does not have a definite endstate yet.

- (285) (a) John built a house.
 (b) John was building a house.

For Comrie, however, (285b) is a paradigm example of "sentences describing telic situations" (1976: 44), but this is obviously a confusion of real world properties and ways of describing them. This has led people like Bauer to introduce a notion of "quasi-atelic imperfectivity" in an effort to bring system to this confusion (1970: 196).

As Dahl (1981: 89) points out, the general problem with all these definitions is that terms like goal, limit, terminal point or end-state are never well-defined. The result seems to be that there clearly is a distinction between telic and atelic expressions (or expressions that do and those that do not have consequences), a distinction which can be observed in English by examining the way these expressions behave in discourse. At the same time we do not seem to be capable of defining what exactly this distinction is.

I will therefore merely restate here the description given in chapter 4: telic event descriptions are those that represent an event as including a point at which a change of state takes place. The changed state is referred to as the consequent state. These expressions can be set apart from other event descriptions because of the ease with which they combine with perfects (which single out this consequent state) and *in*-adverbials (which give the amount of time it took to reach the point at which the change of state took place). The entailment they lack when they are used with a progressive auxiliary, the observed ambiguities with *almost*, or the co-occurrence restrictions on *stop* and *finish*, can similarly be given an explanation in terms of the aspectual network and the temporal/aspectual ontology it embodies.

7.4. Aspect and compositionality

The account presented here does not constitute the first attempt to develop a theory which assigns aspectual categories at the sentence level. As was briefly mentioned in chapter 4, this kind of approach has been proposed by various authors; Verkuyl (1972) probably contains the earliest statement of the idea that the aspectual nature of a sentence is determined by the nature of the constituents out of which the sentence is composed. Some of his conclusions, although somewhat outdated in their technical details because of the generative-transformational framework in which they are formulated, nevertheless seem very similar in spirit to the claims made here.

Verkuyl reduces the notion of aspect to the distinction between durative and non-durative event

descriptions. "Durative" and "non-durative" are syntactic features that are not assigned to any constituent in the surface structure, but that come into existence after the composition of certain constituents. Verkuyl (1972: 106) formulates 2 schemas (one of which is given in 286) which specify whether a sentence will be durative or not by describing the type of verb and noun phrases that make up the sentence.

(286) Nondurative scheme:

$$S^{[NP[SPECIFIED\ QUANTITY\ OF\ X] + VP[V[VERB] + NP[SPECIFIED\ QUANTITY\ OF\ X]]]}$$

In this scheme, VERB stands for subcategorial nodes such as "movement", "perform", "take", "add to" or "transition", i.e. for verbs like *walk*, *play*, *drink*, *build* or *die* respectively; the category SPECIFIED QUANTITY refers to the countability, finiteness or delimitation of the noun phrase, ruling out unmodified plurals or mass nouns. The scheme describes sentences such as (287a) and (b) but not (c) as non-durative sentences:

- (287) (a) John played the cello sonata.
 (b) Harry ate a sandwich.
 (c) Harry ate crisps.

This scheme, and its durative counterpart, determine what kind of aspectual adverbial can occur in a sentence. The underlying structure of a sentence like (288) is given in (288').

(288) John walked for hours.

(288') $NP[S[John\ walked]]\ VP[lasted_{PP}[for\ hours]]$

A nominalization transformation applied to (288') results in (288''):

(288'') John's walk lasted for hours.

Verkuyl claims that a similar transformation turns the verb phrase *lasted for hours* into the durational adverbial in (288). The scheme in (286) embodies a syntactic constraint on this Adverbialization transformation: if the subject S in (288') dominates a set of categories fitting into the non-durative scheme, the transformation from (288') to (288) will be blocked. This rules out sentences like (289a) if they refer to a single event; the co-occurrence restrictions do allow the generation of (b):

- (289) (a) *John walked a mile for hours.
 (b) John walked a mile in less than 10 minutes.

In short, aspect (or rather, its reduction to the two categories durative and non-durative) is a set of syntactic categories which can be assigned to certain sentences, provided the sentences are composed of the right kind of syntactic categories. Syntactic constraints determine whether such a sentence can be combined with certain aspectual adverbials.

Dowty has argued that this kind of syntactic approach misses the point of what aspectual studies are about (1979: 63-65). First of all, Verkuyl does not explain *why* (289a) should be blocked. It would be just as easy to write a grammar that allows (a) and rules out (b). Yet, there is probably no language for which that grammar could be used. Secondly, Dowty argues, a notion like "durative" is a semantic notion at least as much as it is a syntactic one. It is the *semantic* properties of certain verbs, of indefinite plural noun phrases, or of certain adverbials, that are responsible for the ultimate aspectual category assigned to the sentence. The effect of Verkuyl's *syntactic* co-occurrence restrictions is simply to reduplicate work that has to be done in the semantic component anyway.

More recently, Dowty (1986) formulated these objections against the way aspectual categories are used in Partee's (1984) and Hinrichs' (1986) Discourse Representation accounts of the narrative movement of time: sentences describing events (though not processes) are interpreted as occurring one after the other; stative sentences (and process sentences) do not have this effect:

- (290) Jedburgh entered the room, closed the door and switched
on the light. The room was hot and dirty.

As was discussed in chapter 2, this phenomenon is accounted for in Discourse Representation Theory by stipulating an update of the current reference time if the most recently processed sentence is of the event type.

Dowty (1986) argues that this is in fact impossible. If a syntactic analysis is made of a sentence which is then used to formulate the model theoretic interpretation, possibly with some intermediate level (such as Discourse Representation Structures), then aspectual class is a category that can only be determined at the level of model theoretic interpretation, *not* at the syntactic level. Hinrichs and Partee, however, use the aspectual category of the sentence at the level of the discourse representation structure, assuming it can be determined on a syntactic basis, to then decide whether or not to update the current reference time.

For example, Dowty argues, what culminated processes have in common

is the notion of a specific goal or task to be accomplished: in some cases it is a specific distance which is traversed or a specific location which the subject (and/or object) ends up at. In other cases it is the destruction of a specific direct object; in still others it is the new state which the object (or subject) comes to be in as a result of the subject's action. If these verbs occur in a simple past tense, then we understand the goal or task to be reached. If these verbs occur in the progressive, then we are not entitled to assume the same task to be accomplished, though we understand that the action the subject performed was the same kind as before (Dowty 1979: 65).

He goes on to argue that a proper semantics of these expressions should account for these

phenomena in terms of these very same notions of time reference, completion of action and definiteness or indefiniteness of object - notions which syntactic accounts merely explain away as co-occurrence restrictions. In the previous section it was argued that although these notions are hard to define, it was in terms of these very notions that an ontology was defined which was used in the previous chapters to give an account of exactly the phenomena enumerated by Dowty. Thus, there is nothing inherent in the theory defended here that should make it fall foul of Dowty's criticisms.

However, Dowty's remarks also have important repercussions for the design of a natural language processing system if one wants to incorporate in it an aspectual theory like the one presented here. Most important in this respect is the design decision about the exact place in such a system of the aspectual network transitions.

One obvious home for these transitions seems to be the grammar. There are currently grammar formalisms that allow for a close match between a syntactic rule and its semantic import. Thus, one could have a rule in the grammar saying that an *in*-adverbial, for example, is something which only combines with something that is of the semantic type "culminated process" to form something of the semantic type "culminated process", with the added specification that the time that elapsed between the onset of the culminated process and its culmination point equals the time given as an argument of the *in*-adverbial.

Now, let us assume that when processing a sentence like

(291) Sue exhaled in less than 5 seconds

the parser finds *Sue exhaled* to be of the right syntactic type for the *in*-adverbial. However, it is a process expression, so a transition is needed from process to culminated process before combination with the adverbial can be executed. The transition by which this aspectual type change can be carried out could also be implemented as part of the grammar: as was shown in Steedman (1977) for a somewhat different set of aspectual transitions, all the transitions in the aspectual network can be represented as a recursive scheme of rewrite rules. Next, the grammar should also contain a mechanism for forcing such a type change to take place: when faced with an expression of the wrong aspectual type, the parser should not quit, but coerce the expression to be of the right type. This is essentially the proposal made by Pulman (1987).

Let us assume that all this is in place in the grammar. Whilst parsing the example sentence (291), the grammar discovers that an *in*-adverbial has to be combined with *Sue exhaled*, which

is of the wrong aspectual type. The type coercion mechanism brings into play the aspectual transition network. A transition is found which changes the process expression into a culminated process by adding a culmination point. The period of exhaling is then said to have taken less than 5 seconds.

However, throughout the previous chapters it was pointed out that every transition path through the network has to be supported by context, be it general world knowledge or specific knowledge about the state of affairs talked about. The interpretation found for the example in (291) is a very plausible one. Consider:

- (291) (I asked Sue to exhale very slowly, but)
she exhaled in less than 5 seconds.

But it is not the only possible interpretation for (291). Another transition can be found in the network, one which squashes the whole process of exhaling into a point, and then - via the culmination node - adds a preparatory process of "less than 5 seconds" leading to the onset of this process. This is a very likely interpretation for (291'):

- (291') (I asked Sue to hold her breath as long as she could. But)
she exhaled in less than 5 seconds.

It is obvious that a system which tries to use the aspectual transition rules to identify the aspectual sense of a sentence needs access to the whole discourse context when making that decision (cf. Webber 1978: 388). So, although a system could be set up in such a way that it contains aspectual co-occurrence rules, allowable transition paths and a type coercion mechanism, the ultimate aim of all this machinery - i.e. deciding on the aspectual type of the sentence and the transitions needed to get to that aspectual type - cannot be decided on at this level of analysis. If we were to set up a natural language system like this, we would be making the same mistake Dowty discovered in Verkuyl's work and in the Discourse Representation Theory approach to temporal matters.

One obvious item that should be removed from a grammar designed as sketched in the previous paragraphs, are the aspectual network transitions. Since they are heavily dependent on context, they should best be left to do their work there, i.e. at the level of model theoretic interpretation of the sentence, or as a task for the database manager in the case of a statement verifier linked to a database.

What we are left with, then, are grammatical rules specifying what input and output categories are appropriate for a given construction. But no attempt should be made at coercing something

to be of the right type. The only thing the *in*-adverbial does in the example discussed above, is to signal that *Sue exhaled* should be a culminated process. When determining the truth value of the sentence, or when verifying the sentence against a database, the aspectual transitions can be used to determine whether, given the world in which the event took place, the expression really belongs to that aspectual category.

Once it is acknowledged that determining and coercing aspectual types should be carried out at the level of model theoretic interpretation or database verification, one could conceivably also abandon the idea that expressions should be signalled to be of a certain type. Thus, in the example under discussion, one could pass on to the database manager the information that there is an event called *Sue exhaled* in the scope of an *in*-adverbial. The database manager would then check its rules to determine what type of expression *Sue exhaled* is supposed to be, given that it occurred with that adverbial.

If we remove all mention of aspectual types from the syntax then we should also remove the rule suggested earlier on, viz. that a process expression with a direct object forms a culminated process expression: this is indeed the kind of syntactic rule which, according to Dowty, explains away a phenomenon that should be handled at the semantic level. Moreover, the aspectual theory offered here does not seem to have the right concepts to explain why this should be a rule of the language in the first place, rather than, for example, its opposite. To decide whether an explanation for this can be given in terms of the aspectual concepts introduced here, one last digression is needed.

7.4.1. Mass terms, bare plurals and aspectual class

As was suggested in the previous section, a rule can be formulated stating that a process verb like *eat* can be turned into a culminated process when combined with a direct object, as in (292a).

(292) (a) John ate a sandwich.

What is required for this transition to be felicitous is that a culmination point can be associated with the process. The direct object apparently makes for the effortless identification of such a culmination point. Yet this transition does not seem to occur in (292b) or (c).

(292) (b) John ate bread.

(c) John ate crisps.

Both (b) and (c) are in need of another transition before they can combine with an *in*-adverbial, whereas they both freely combine with a *for*-adverbial. This indicates that (292b)

and (c) are process expressions.

This phenomenon can also be noted with noun phrases in other positions than the object position, as shown in (293). The (a) examples are the normal culminated processes; the (b) and (c) examples are processes.

- (293) (a) We drove through my birth-place (in 4 minutes flat).
 (b) We drove through snow (for hours on end).
 (c) We drove through quaint little villages (all day long).

These differences in aspectual characterization seem to be caused by the referential properties of the nouns in the direct object noun phrase (in 292) and the prepositional phrase (in 293). In the (a) examples we find count nouns; the (b) examples contain mass nouns; the (c) examples contain plural count nouns without any modification (commonly known as "bare plurals"). The effect mass nouns and bare plurals have on the aspectual character of the sentence seems to be that when they occur as the argument of a process verb they do not facilitate the transition from process to culminated process.

This is a phenomenon that has often been noted in the literature on aspectual classification. It is usually explained by appealing to a semantic feature shared by mass nouns and bare plurals, which interacts in some way with the semantics of the verbal expression (L. Carlson 1981, Mourelatos 1981, Harlig 1983, Hinrichs 1985). In what follows, I will first examine the claim that there is such a common feature. Next, I will show that this approach does not give a complete account of the contribution that these noun phrases make to the aspectual interpretation of sentences.

The important semantic feature mass nouns and bare plurals have in common is the principle of distributive or cumulative reference. This was first described for mass nouns as the property of divisibility which these nouns seem to have: any part of water is still water; any part of smoke is still smoke. Intuitively, this seems right, yet we know one cannot really divide gold into ever smaller parts and still retain gold. Although this is an epistemological problem, the principle of partitivity was rephrased in terms of additivity rather than divisibility: water added to water gives water; a table added to a table does not result in a table (cf. Pelletier 1979 and references therein).

It was then noticed that bare plurals share the same semantic principle of additivity: adding *students* to *students* leaves *students*, adding *bicycles* to *bicycles* gives *bicycles*. L. Carlson (1981)

also claims that the divisibility principle fails with bare plurals for the same reason as with mass nouns: a subdivision of *children* still has *children* as its result, up to a certain point beyond which the division leaves something more gruesome.

Once it was established that bare plurals and mass nouns share the property of distributive or cumulative reference, it had to be established how this feature interacts with the semantics of the verbal expression to explain the aspectual changes. An obvious link lies in the often made observation that part of the aspectual classification in the verbal domain is itself open to a mass/count distinction. Just as water can be divided into smaller parts still giving water, so *John is working in the garden* can be divided into smaller parts which can still be described as *John is working in the garden* (cf. Bennett & Partee's subinterval property). And just as the principle of divisibility can be taken too far (for example, chopping up gold into ever smaller pieces until one is left with small atoms which are *not* gold anymore), there is also a problem with the subinterval property normally ascribed to processes: subintervals of *John is waltzing* can still be described as *John is waltzing*, if one does not make the subintervals too small (i.e. smaller than a 3-step sequence). The upward entailing principle of additivity seems to give better results: any process of *John's waltzing* added to *John's waltzing* still results in *John is waltzing*. A culminated process expression like *John painted the house* does not have this property. This indicates that processes do and culminated processes do not refer in a cumulative way.

The claims emerging from analyses like these were that the non-countability feature of mass nouns and bare plurals interacts in such a way with the referential properties of the verbal expression that these verbal expressions themselves acquire the non-countability feature.

However, nothing in the aspectual theory offered here seems to provide a way of talking about the referential properties of a verbal expression as somehow involving a (non-)countability feature. So, not only would Dowty be right in arguing that it would be highly inappropriate to formulate a syntactic rule to capture what is clearly a semantic principle, we also do not seem to be in a position where we can argue *why* this rule should be a part of the language.

It is not clear, however, that the countability principle (or its test, the additivity principle) makes all the distinctions it should be making. Modifiers like *some*, *a little* or *a few* seem to obey the additivity principle, or it would at least seem equally odd to classify the expressions they form as being countable. Yet, when they are used as a direct object with process verbs,

the result seems to be culminated process expressions (294), as is borne out by the fact that they can occur quite easily with a perfect auxiliary (295) and that when used in the progressive they seem to lack the entailment that processes have in this context (i.e. 296 does not entail 295b):

- (294) (a) John drank some beer.
 (b) Mary ate a little caviar.
- (295) (a) I've eaten some sandwiches.
 (b) I've read a few articles.
- (296) I was reading a few articles

From this observation, Harlig (1983) hypothesizes that all process verbs with a direct object that contains any kind of modifier form culminated process expressions:

- (297)
- | | | |
|-----------|-------------------|-----------------------|
| John read | the articles | |
| | several articles | |
| | a lot of articles | (in less than a day). |
| | four articles | |
-
- | | |
|--------------------------------------|-----------------|
| It took John more than a day to read | some article. |
| | a few articles. |

Harlig recognizes that these modifiers do not really form a totally unified group, since they contain articles, numerals, and (other) adjectival expressions. Mittwoch (1982) suggests that there is a semantic unity, however, in that they all express a delimited quantity. The fact that *some* and *a little/a few* seem to be less prototypical members of this group she explains by pointing out that, although they describe a delimited quantity, this quantity is not specified. Yet, as was pointed out with example (296), they do form culminated processes.

An explanation of why the Harlig/Mittwoch hypothesis is so successful is rather straightforward in terms of the aspectual network. The transition from process to culminated process is felicitous if the context in which the construction is used is such that a culmination point can be associated with the process. In the familiar example (298), a very special context has to be invoked before sense can be made of the utterance.

- (298) John ran in 4 minutes.

The speaker can make it easier on his hearer, however, by providing extra clues as to what sort of culmination point he is thinking of. This can be done by adding a direct object:

- (299) John ran a mile (in four minutes).
 (300) Mary ate 2 bags of crisps (in less than a minute).

The direct object is *not* itself the culmination point. The *2 bags of crisps* or *a mile* are rather an indication that the process had a particular culmination point associated with it and provide extra context to help determine that point. For sentences like (299) and (300), the hearer will

have no problem identifying that particular culmination point.

The problem with unmodified direct objects is that they do not help the hearer in determining what the culmination point is.

(299') John ran miles and miles.

(300') Mary ate bags of crisps.

(299') and (300') contain a direct object. But as was just noted, it is not the direct object itself that describes the culmination point - it only helps the hearer to find a suitable one. The direct objects in (299') and (300') are too vague to be of any help; what is needed is a direct object that denotes a "specified" (Verkuyl) or "delimited" (Mittwoch) quantity.

To summarize, the attempts in the literature to find an explanation for the influence of bare plurals and mass nouns on the aspectual characterization of event descriptions seem to have missed a generalization by ignoring the general contribution modified noun phrases make to the aspectual character of a sentence. A simple rule can be formulated that a process verb combining with such a noun phrase in object position results in a verb phrase of the culminated process variety; a transitive process verb that combines with an unmodified noun phrase results in a process verb phrase.

It is true that, with a proper semantic theory of all varieties of modified noun phrases, this rule could be removed from the syntax and located at the level of model theoretic interpretation. As long as such a semantics is not in place, we can keep the rule at the level of syntax, with the defence that the formulation of the rule at least does not suffer from the arbitrariness Dowty ascribes to Verkuyl's rules: with the aspectual theory offered here we can explain why this rule - and not, for example, its opposite - should be part of the grammar. The explanation, moreover, can be given in terms of the same concepts and by making use of the same referential properties of verbal expressions which were used elsewhere in the theory.

7.5. Conclusion

A major theme of the previous chapters was that understanding the temporal structure of discourse depends on being able to assign linguistic entities to an aspectual class. In the literature on aspect there is a wealth of tests that can be used to determine the aspectual category of a given expression. It was argued that they should be looked upon as observed phenomena of the language for which a theory of aspect like the one presented here should give an account. It follows that the tests that were singled out here to guide the aspectual classification of

expressions embody the principles that underly the aspectual network and reflect the functional accounts of temporal expressions given in chapter 5.

Although one can talk about the aspectual category of a verb, a verb phrase or a larger unit, it was pointed out in this chapter that such a classification should still be thought of as a classification of propositions. And ultimately, to determine the overall temporal structure of a discourse, it is important to realize that the entities one is classifying according to their temporal properties are utterances of sentences used in context.

Because of this, it was argued that determining the aspectual class of an expression cannot be carried out at the level of syntax, but belongs at the level of model theoretic interpretation. It does remain possible to have rules in the grammar that specify what aspectual type a particular expression should belong to for the sentence to be true. But no attempt should be made at that level to determine whether the expression *is* of the right type, and - if not - how its aspectual type can be changed. In the next chapter, an implementation will be presented that embodies this idea: coercing an expression to be of the right type, and checking the aspectual transition network as to how this can be accomplished, are tasks carried out by the database manager because only at that level is enough general and specific world knowledge available to guide this task.

Chapter 8

Temporal information for natural language processing

8.1. Introduction

It was argued in the previous chapters that the identification of the correct ontology is of crucial importance in the design of a principled and unified semantics of natural language categories like tense, aspect and aspectual/temporal adverbials.

The identification of the correct ontology is also a vital preliminary to the construction and management of temporal databases. Since information can only be stored to the extent that it fits the preconceived formats of the information storage device, it follows that the efficiency of man-machine interaction can be increased dramatically if the datastructures used by the program to organize a particular type of information correspond in a natural way to the structures people use to organize that information (cf. Woods 1984). A bad fit between datastructures and human concepts will almost always result in a loss of interaction flexibility. In the case of natural language systems the penalties for a bad fit will be that some of the information expressed in the language will be lost when it is being forced into the incompatible datastructures. Conversely, these datastructures cannot be queried very easily using natural language since the conceptual structure implicit in the query does not fit the conceptual structure of the database.

Since we have been able to show that the concepts people manipulate when using temporal expressions belong to a specific, episodic ontology, it follows that the exchange of temporal information between users and machines could be improved if information systems stored temporal data not just as points or intervals on a time line, but according to the principles of that ontology. In this chapter, I will present an implementation of these ideas in the form of a simple statement verifier that checks input against a database.

Before turning to this implementation, I will compare the episodic ontology with proposals that have been made elsewhere for the representation of temporal relations. Proposals discussed here do not just come from the area of Artificial Intelligence but also from the literature on database systems. The reason for this should be obvious: the main goal of Artificial Intelligence is the design and implementation of a physical world in terms of which systems will be able to perform certain tasks "intelligently". In its attempt to design such a representational

scheme, Artificial Intelligence shares many goals with research into database design (cf. Wong & Mylopoulos 1977).

The purpose of this chapter is not to give an exhaustive overview of formalisms developed for the representation of and reasoning about time and events, but rather to examine whether the proposed representation systems deal with time in such a way that they could be linked up with a natural language front-end that processes time-related statements.

The discussion will therefore focus on those systems that were developed with natural language applications in mind, starting off with a system that was developed especially to extract temporal information from texts and to store this information in such a way that it can be accessed later to answer questions about these texts. I will then move on to other representation formalisms, still largely ignoring issues of temporal reasoning proper and focussing on those aspects of the formalisms that may prohibit their use in a natural language understanding system. In line with the general ontological theme of the previous chapters, theories and formalisms will be discussed with special reference to their underlying model of the world.

8.2. Extracting temporal information from text

As part of the Linguistic String Project in New York a processing system was developed whose task it was to extract information from hospital discharge summaries, and to store this information in such a way that it remains available for answering questions (Hirschman 1981a, 1981b; Hirschman & Sager 1981; Hirschman & Story 1981). Here is a typical example of the sort of text this work is involved with.

This is the first admission for this 72 year old woman with presumed adenocarcinoma of the lung. The patient was well until 6-74 when she had an episode of severe dyspnea while in Maryland. She was admitted to a local hospital where she was found to have a pleural effusion. She underwent pleural biopsy and cytology which showed adenocarcinoma. In 7-74, she had 5 millicuries of P32 instilled into the left pleural cavity.

The aim of the program is to map this kind of text into an information table, with one column for each type of information that can occur in patient histories and one row for each assertion in the message. Some examples of (partial) information tables will be given shortly. In what follows, I will restrict the discussion to the way temporal information is treated.

The first step in the process is to break the text down into events, corresponding to simple assertions. An expression like *she was well until 6/74* is expanded into two distinct events - one of her being well, lasting up to June 1974, and an event of her not being well which starts

in June 1974.

Associated with every event is a time point or period, calculated by taking a reference time and adjusting it forwards (+) or backwards (-) in time by a certain number of time units. Thus, an expression like *a week before admission* gets the following time representation:

(301)

			Adjustment		
Event	Relation	Ref.time	Direction	Quantity	Unit
	At	Admission	-	1	Week

This sort of information, needed to locate events relative to one another as well as on a calendar, is given most clearly by expressions like dates, certain prepositional phrases and time adverbials. Once such an expression is found, its value has to be computed, which means first of all finding the appropriate reference event. In the case of *now* or *yesterday*, the reference event is the time of narration; for *then*, the reference event is the last narrated topic. In other expressions it is usually given explicitly, as in *after discharge*, *this week* or *two days before admission*. Then the adjustment has to be computed. The direction of the adjustment is stated separately for different expressions: positive adjustment for *after*, *later*, *subsequently*; negative adjustment for *prior*, *previously*, *past*, *before*; no adjustment for *at*, *on*, *now*. Also important is the sort of relation denoted by the temporal expression. Durative expressions, such as *for*, *during* and *throughout* are marked as a *from_to* relation; punctual expressions are marked as *at* relations.

Tense and aspect are, of course, also taken into account when computing the relative time of events. In a sense, however, they are less important. Most verbs in the discharge summary occur in the past. The only important information tense carries in this case is that the narrative is still going on, and that some general principles concerning the forward movement of narrative time still hold.

The treatment of the present perfect is quite remarkable in its simplicity: it is taken to refer to an event which started at (or after) the time of the last narrated topic, and continues up to the time of narration. Thus, a text such as *High fever was first noted 1 day before admission (E7)*. *Fever has persisted (E8)* will be divided into events (as noted between brackets) and treated as follows:

(302)

			Adjustment		
Event	Relation	Ref.time	Direction	Quantity	Unit
E7	At	Admission	-	1	Day
E8	From to	E7 Narr.time			

Relative time information about the events can also be given by means of connectives (like *when*, *while*, *before* and *after*), verbs (like *precipitate*, *cause*, *precede*, *follow*, *coincide with*) or certain nominal expressions (e.g. *the source of*, *the result of*). Again, all these have to be recognized during the parsing stage, and it has to be determined for each of them what time information they contribute. This is again facilitated by sorting these words into separate semantic classes, for example a class for words indicating the beginning of an activity or state (*from*, *development*, *onset*, *new*) or a class of words denoting a change of state (*heal*, *improvement*, *worse*). The treatment of a connector like *when* is illustrated in (303), which gives the time representation for *Patient was discharged when signs of pneumonia were gone*.

(303)

Event	Conn.	Text	Relation	Ref.time	Adjustment
E1	When	Patient was discharged	At	Last narrated topic	0/+
E2		Signs of pneumonia were gone	At	E1	

In fact, this diagram shows that the treatment of *when* is the exact opposite of what one would expect: in (303), the time of the subordinate clause is expressed in terms of the time of the main clause. This seems counterintuitive. A *when*-clause is "self sufficient" as far as a reference time is concerned, because its function is exactly to bring into focus a uniquely identifiable event with respect to which the main clause can be interpreted. The time of the main clause should have been described in terms of the time of the subordinate clause.

It is, of course, also important for the system to recognize events that have a known time: *admission* and *discharge* are the most important ones in this particular world of discourse. They allow the time talked about to be divided into 5 stages: before admission, at admission, after admission and before discharge, at discharge, after discharge. Every event can then be tagged with a more general reference point, indicating to which of these 5 stages the event temporally belongs.

A crucial point in determining the exact temporal relation between events is the recognition of multiple reference to the same event. Consider:

- (304) A transfusion of 100 cc red blood cells was given. After completion of transfusion, patient lapsed into a coma.

Failure to recognize that both mentions of transfusion refer to the same event will result in a representation with two transfusion events and no coherent time relations between them. Definite articles are usually a good clue, of course, but are also routinely omitted from this sort of text. This results in a much more complicated procedure of checking, for each event before it is entered in the data base, whether it has been mentioned before.

A last indicator of temporal relations is narrative time progression: in a narrative, such as a discharge summary, time is assumed to move forward unless there is information to the contrary. In a text like (305)

- (305) She was admitted to hospital. She underwent a biopsy.

the program records that the time of undergoing the biopsy is later than or equal to the time of admission to the hospital. The first event is taken as reference time, and updated in the direction "0/+". When a co-ordinate conjunction connects two assertions or VPs, it is also taken to indicate forward movement of time, as in (306):

- (306) She developed seizures and was given phenorbital and valium.

Given phenorbital and valium is later than *developed seizures*. A conjunction of two NPs is expanded into two events (in this case *given phenorbital* and *given valium*) but the same time is assigned to both events. However, the system does not distinguish between the aspectual character of sentences when deciding about the narrative progression. Thus, in a sentence like (307)

- (307) Blood gases were monitored throughout the next few days and gradually returned to normal.

return to normal will be situated just after monitoring the blood gases.

After all this computation has been done, the events are located on a time line. In the example above, the third sentence is divided into three events:

- E8 = she was admitted to a local hospital
- E9 = where she was found
- E10 = to have a pleural effusion

All three are found to occur at the same time, because of their connectives and because there is no information to the contrary. The next sentence is also divided into three events:

E11 = she underwent pleural biopsy
E12 = and cytology
E13 = which showed adenocarcinoma

Because of linear time progression, E11 is supposed to come just after E10, and E12 just after E11 (adjustment 0/+, i.e. zero or something); E13 has the time of E12 because the two events are connected by a relative clause, which is treated as a non-temporal connective (as long as there is no time information to indicate otherwise).

The steps the system has to go through in order for it to be able to answer the question *When was cancer first detected?* are as follows. First, the system looks for (synonyms of) cancer, and finds two mentions of the adenocarcinoma (in E3 and in E13). Then, it is computed which of these events occurred earlier. E3 has a reference time *at admission*; E13 is *before admission*. So E13 is the earlier one. The system then computes the time of E13: E13 is just after E11 (adjustment 0/+), which is just after E8 (adjustment 0/+), which is just after the time of admission to hospital, June 74 (adjustment 0/+). The sum of three occurrences of 0/+ is 0/+; hence, the time of E13 is June 74 adjusted by 0/+, or: cancer was diagnosed first at a time later than or equal to June 74.

In fact, it should be clear from looking at the example text that the question about the first signs of cancer should have an upper bound of July 74. The program does not see this because events only have one reference point. Future implementations are promised where an event can have several reference points.

The results of the Linguistic String Project System are impressive. It should be borne in mind, however, that these results were obtained because the intended domain of application was well-defined and fairly restricted from the start. As a result, the Linguistic String Project System does not have that high a degree of transportability. True, conversion of the system to handle Navy messages about shipboard equipment failures was successful. Yet, as Marsh & Friedman (1985) remark, this success was largely due to the fact that the original medical domain and the new Navy domain share important semantic patterns: in both domains, the processed texts talk about system failures and about ways to treat these failures.

This restrictiveness also shows up in the way they handle certain temporal phenomena. As was pointed out before, *when*-clauses are given a counterintuitive treatment but nothing important follows from that in this domain. Similarly, by downplaying the importance of the aspectual character of event-descriptions, not all indicators of the forward movement of narrative time

are correct, but again this seems to be only a minor worry for the type of text this system is designed for.

Finally, the underlying ontology used in this system is one of events ordered on a time line as unanalyzable entities. No consequential links are asserted to exist between events connected by means of a *when*-clause. This obviously results in a loss of information and could easily lead to the generation of statements that are open to misinterpretation to a naive user.

As was mentioned above, in recent years the work on the Linguistic String Project was transported to the domain of casualty reports about failures of starting air compressors. Although this system, the PUNDIT system (Hirschman et al. 1987), is an extension to the Linguistic String Project, there are a number of important differences, notably in the design of the temporal component (Passonneau 1987). After a first stage, where sentences describing general or habitual states of affairs are separated from those describing one-off events, the temporal component computes the structure of these event descriptions (i.e. examines how the state of affairs it describes evolves through time). To this end, propositions can be classified as states, processes or transition events (transition events correspond to what are referred to here as events that have consequences associated with them); each one of these has a different type of interval or intervals associated with them. For example, a sentence like

(308) The pump has seized

is analyzed as consisting of a transition event, the time argument of which is a moment (viz. the point at which the pump seized), and of a result, which is the state or process of being seized, and whose time argument is a period.

With this description of events as consisting of a time period, leading up to but not necessarily reaching a transition point, and this in turn associated with a new state or process, the underlying ontology in the PUNDIT temporal component comes very close to the one presented here. This components can handle a wide range of phenomena, always within the particular domain of application. As a result, no uniform account of the progressive seems to exist, in that no attempts are made to deal with the difference between the progressive of a culmination expression and that of a point expression. Nor are any attempts made to deal with the imperfective paradox - again, probably, because the problem does not really arise in this domain. Consider:

(309) The pump is failing.

Although *fail* is a transition event, it seems likely that from a statement like (309) in a casualty report one could conclude to (309'):

(309') The pump has failed.

For reasons similar to those described above (chapter 2), Passonneau also offers a sophisticated extension to Reichenbach's R,S,T system so as to take into account the internal complexity of events when ordering events with respect to each other or with respect to the time of writing of the casualty report. However, that ordering of events is strictly temporal. Notwithstanding the richer ontology available, no attempts are made to integrate events as a functional part of other events, either as part of their preparation or their consequences. *When*-clauses, for example, are treated as temporal coincidence. Although this does not seem to lead to great difficulties, the same caveats hold here as were noted before with respect to the Linguistic String Project.

8.3. Temporal representation models

8.3.1. The situation calculus

The most influential theory in Artificial Intelligence for modelling the behaviour of events has been the Situation Calculus of McCarthy & Hayes (1969). In it, the world is described as a set of *situations*; an action is defined as a function from one situation to another.

Situations are usually defined as snapshots of what the world looks like at a single instant in time (e.g. Allen 1984: 124). But such a description is rather misleading: situations have no measurable time dimension; it cannot be known whether they only lasted for a moment, or for longer. They exist until an action is performed, which by definition creates a new situation. They *are* like instants, however, in that they are indivisible entities, not allowing a relation of overlap between them. Schematically, the ontology underlying this calculus can be represented as follows:

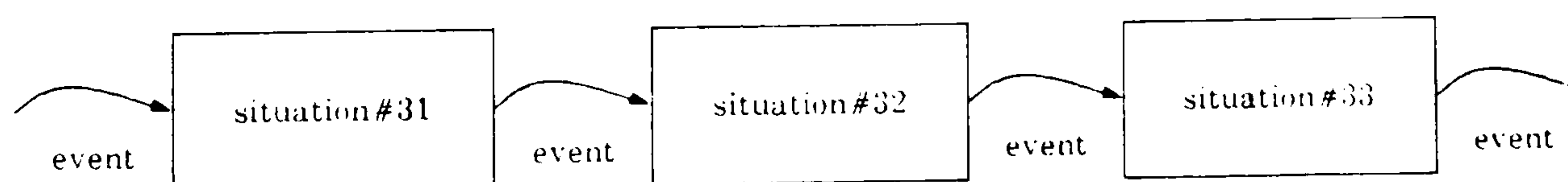


Figure 5: The ontology underlying the situation calculus.

The states or situations are described in terms of state predicates; the events or actions can be described in terms of the prerequisites on the initial as well as the resulting situations. Actions are simulated by adding facts to or deleting them from the database. The database thus describes, at every point of the world's history, what is presently true. It does not represent

any other situation at the same time.

There are a number of problems attached to this sort of representation. First of all, it cannot be extended easily to describe or represent simultaneity: an event changes one thing in the current situation, and by doing that changes that particular situation into (one) other situation.

Another problem with this model is that every action is equated with change. Thus, it becomes impossible to model actions that involve no change, or actions that restore the world to the state it was in before. A typical example is *running around a track*: although one can say something has changed (e.g. in terms of the physical condition of the runner, or in terms of his memory of the event) it is unclear how that could be used to model the running - i.e. to model it as an operation from a world where the runner is not tired to one where he is.

A third problem is that the Situation Calculus does not allow one to model past or future time: at any point in time the world is exactly as described in the database, and no other information is available. Partially ordered events also constitute a problem for the Situation Calculus. The knowledge that event1 came before event5 and event2 also came before event5 cannot be represented in this framework. Events have to be totally ordered.

However, the most notorious problem associated with this ontology is the "frame problem" (Hayes 1973; Kowalski 1979): when an event occurs or an action is performed, only one element in the situation changes; in the newly created situation, a large set of facts will remain unaffected. It is computationally very inefficient when, with every event, the system has to determine explicitly that all statements that are true of a situation and are not affected by an event continue to be true after the action has been performed.

Various methods have been proposed to overcome this problem such as the use of "frame axioms" (cf. Kowalski 1979), or the STRIPS-assumption (Fikes e.a. 1974). Further discussion of these and of their shortcomings when planning influential actions would be outside the scope of this chapter (but see Waldinger 1977). At this point, it suffices to note that an ontology using global situations runs into severe problems when modeling events.

The shortcomings of the Situation Calculus have been widely acknowledged from early on (cf. Hayes 1973). The proposed solution, however, was not to change the ontology but to add a notion of time to it. This resulted in work usually associated with McDermott and Allen,

although in Artificial Intelligence as well as in the database design literature similar formalisms were proposed independently and often without taking the worries about the Situation Calculus as their *raison d'être*. It is to some of these formalisms that we will turn next.

8.3.2. Ontologies with temporal characteristics

The simplest way of combining the Situation Calculus with an explicit notion of time is by attaching dates to the situations. The resulting ontology can be represented as follows:

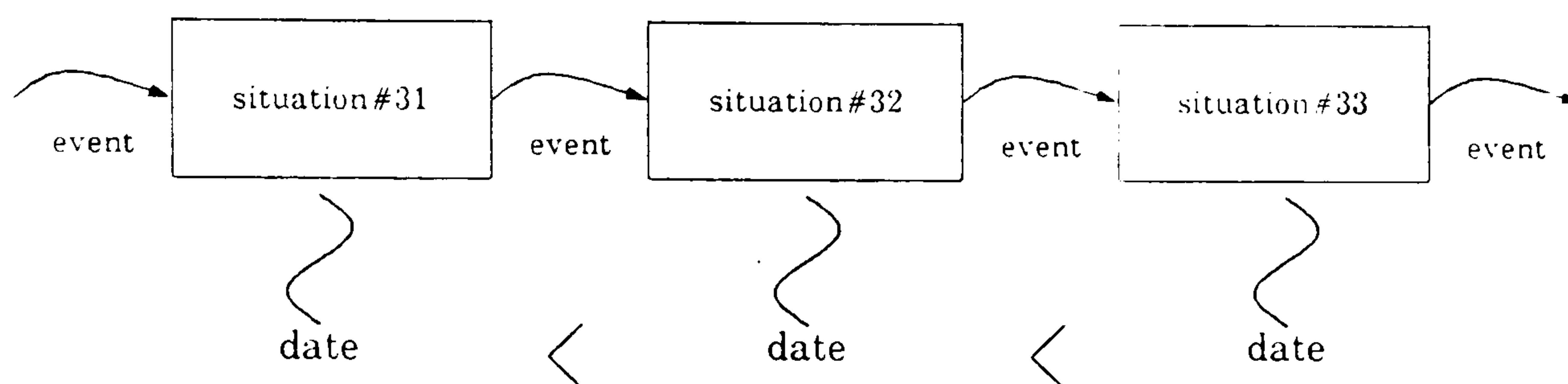


Figure 6: A "dated" situation calculus.

Ontologies like this one have been proposed in the database literature as rollback databases (cf. Snodgrass & Ahn 1986). Where traditional "snapshot" databases only store that version of the world which is currently valid, rollback databases store all past states of the database indexed by time. This means that, when the database is updated, the new database does not replace the old one but is added to it. A simple database with yearly updates, storing information about employees, the department they work in and the salary they earn, could be represented as in Figure (7). In such a database, historical queries are carried out by rolling back to a previous state of the database to then verify the query against that static version of the database. It is important to realize that the times used to index the past states in the database are transaction times, i.e. the times at which the update was carried out rather than the time at which the change really occurred in the world. As a result, a rollback database records the history of the database rather than a history of the real world: changes can only be made with respect to the most recent snapshot state; there is no way of incorporating at a later stage information about earlier events.

Implementation of rollback databases is costly, mainly because of the data redundancy one is bound to get with this sort of approach - a data redundancy akin to the computational overheads noted with respect to the Situation Calculus. In the area of database construction excessive duplication of information in the data storage device is not considered to be a necessarily

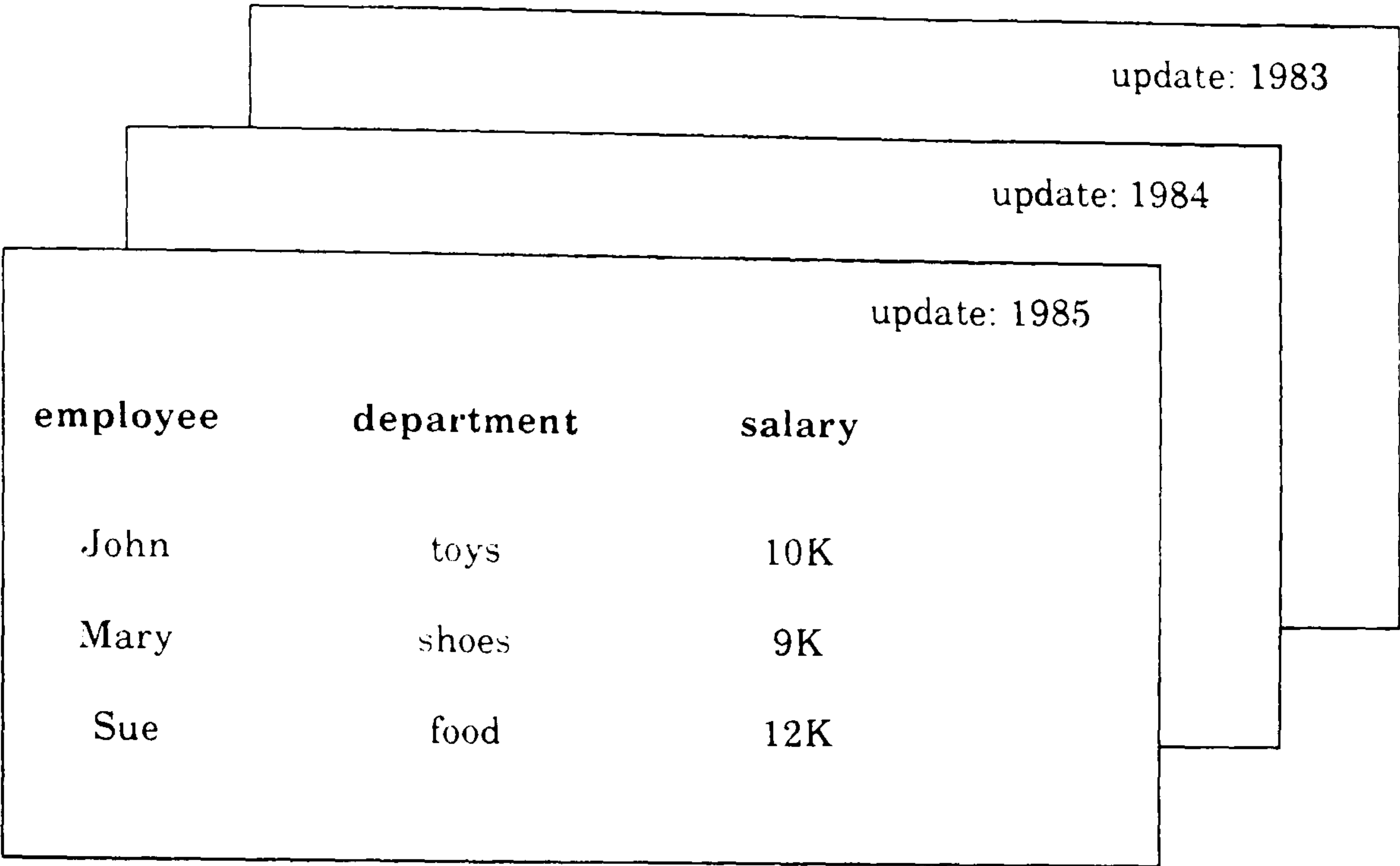


Figure 7: Example of a rollback database

negative characteristic, due to the decrease of storage costs and the emergence of new mass storage technologies that allow fast access (cf. Copeland 1982). If we assume, however, that in natural language processing updates of the event structure occur with every event described in a text, a rollback model to represent such an event structure would cause immense computational overheads.

Allen (1984) presents a formalism for reasoning about time that can be used by problem-solvers and planners (Allen & Koomen 1983) as well as in natural language understanding systems. The ontological basis of Allen’s system is a world which, like the ontology in the Situation Calculus, consists of situations and events. It can be described by temporally qualified assertions. But unlike the traditional Situation Calculus, assertions in Allen’s formalism can indicate both how long a situation lasted or how long it took for an event to be achieved. In line with our previous schematic representations of underlying world models, Allen’s ontology can be represented as follows:

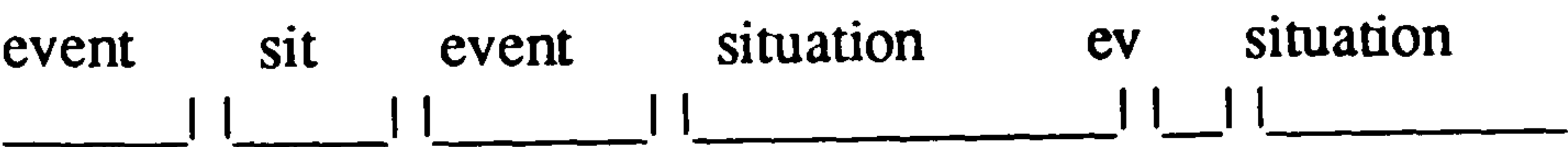










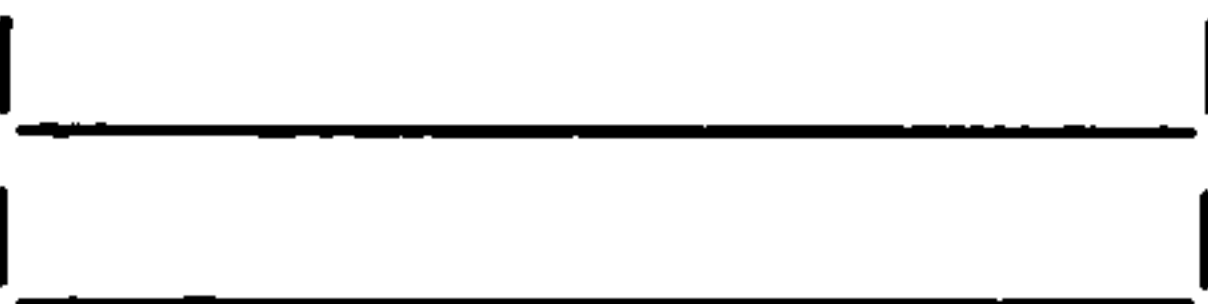


Figure 8: Allen’s world model.

Since the periods associated with events or situations are the only times that can be identified in the world, Allen takes them as basic in his temporal logic. The number of relations that can

hold between these temporal intervals is limited to 13 (as was described in Vilain 1982). Each of them is represented by a predicate in Allen’s logic. They are summarized in (310). In Allen & Hayes (1985) it is shown that any one of these relations can be chosen as a primitive in terms of which all the other relations can be defined.

(310)

Relation	Symbol	Pictorial example
Inverse relation		
X overlaps Y	o	
Y overlapped by X	oi	
X during Y	d	
Y contains X	c	
X starts Y	s	
Y started by X	si	
X finishes Y	f	
Y finished by X	fi	
X meets Y	m	
Y met by X	mi	
X before Y	<	
Y after X	>	
X equals Y	=	

A set of axioms defines the behaviour of each of these predicates, most importantly the transitivity relations that can hold between intervals. An example of such a transitivity rule is given in (311). A full description of these rules can be found in Allen (1981).

(311)

MEETS(t1, t2)

& DURING(t2, t3)

=> [OVERLAPS(t1, t3) or DURING(t1, t3) or (MEETS(t1, t3))]

The ontology Allen works with is slightly more complex than was suggested in Figure 8 in that he distinguishes between two kinds of events, corresponding to our processes and culminated processes. Allen refers to them as "processes" and "events" respectively; states or situations he labels "properties". Properties, processes and events can be distinguished on the basis of the characteristics of the temporal intervals during which they hold or occur. To describe these differences, Allen introduces three predicates - one for each event-type. A

property *holds* over an interval; this is defined such that it also *holds* at all time points during that interval. A process is said to be *occurring* over an interval, which means it is also *occurring* over all its subintervals. And an event is said to *occur* over an interval; this means it *occurs* over none of its subintervals.

Take, for example, the event of a ball changing place from a source position to a goal position. This can be represented as follows:

(312) CHANGE_POS (Ball, x, y)

To assert that the ball actually moved, it has to be asserted that the event described in (312) occurred over an interval. The movement of a particular ball (*Ball1*) from position1 to position2 over a time T5 can be represented as in (313):

(313) OCCUR (CHANGE_POS (Ball1, Pos1, Pos2), T5)

The definition of *occur* (i.e. the stipulation that an event occurs over none of its subintervals) and the necessary conditions for the class of events involving a change of location (given in 314) completely describe the meaning of (313).

(314) OCCUR (CHANGE_POS (object, source, goal), t)
=>
t1, t2 such that
MEETS (t1, t) & MEETS (t, t2) &
HOLDS (at (object, source), t1) &
HOLDS (at (object, goal), t2).

Allen & Kautz (1985) contains an example of how this machinery can be used to express event relations described in a natural language text. Consider the following example:

(315) Ernie entered the room and picked up a cup in each hand.
He drank from the one in his right hand, put the cups back
on the table and left the room.

The first sentence introduces the following temporal assertions:

(316) ENTER (m) HOLDR
ENTER (m) HOLDL

(316) expresses the facts that the interval associated with the event of *entering the room* MEETS the interval during which Ernie holds a cup in his right hand (HOLDR) as well as the one during which he holds a cup in his left hand (HOLDL). An algorithm using constraint propagation specifies the relation between the two *holding* events:

(317) HOLDR (mi) ENTER <= 316
& ENTER (m) HOLDL <= 316
=> HOLDR (= s si) HOLDL

(317) states that the interval associated with the event of *holding a cup in his right hand*

equals, starts or is started by the interval during which he *holds a cup in his left hand*.

The second sentence can be represented as follows:

(318) DRINK (d) HOLDR

Incremental constraint propagation will again determine what the relation is between the newly introduced *drinking* event and the events already in the network (or database):

(319) (a) DRINK (d) HOLDR ≤ 318
 & HOLDR (mi) ENTER ≤ 317
 => DRINK (> mi) ENTER
 (b) DRINK (d) HOLDR ≤ 318
 & HOLDR (= s si) HOLDL ≤ 317
 => DRINK (> d f mi oi) HOLDL

The final sentence of the example narrative introduces the following propositions to the database:

(320) HOLDR (m) LEAVE
 HOLDL (m) LEAVE

Further use of the transitivity axioms leads to the inference that Ernie drank while holding the other cup:

(321) HOLDL (c) DRINK

This conclusion about the relation between HOLDL and DRINK is much more specific than the one we arrived at before (cf. 319b). Allen's constraint propagation algorithm only derives significant new assertions about the relationships between intervals and automatically halts when no more can be drawn. This type of behaviour is much more constrained than that exhibited by general-purpose theorem provers when faced with a collection of time-related axioms. It can, however, be shown that determining consistency of statements in the interval algorithm is NP-hard. Allen's constraint propagation algorithm is sound but not complete in polynomial time (Kautz & Allen 1986).

Allen observes that many events (our culminated processes) have closely related processes. For example, the *event* of an object falling from x to y involves a *process* of falling. Allen therefore defines this event as a composite of a CHANGE_POS event and a FALLING process:

(322) FALL (obj, source, goal)
 =
 COMPOSITE (CHANGE_POS (obj, source, goal), FALLING (obj))

Given this definition of a *falling* event, the assertion that such an event actually occurred over an interval will look as follows:

- (323) OCCUR (FALL (), t)
 iff
 OCCUR (CHANGE_POS (), t)
 & OCCURRING (FALLING (), t)

This specification of the relation between events and processes gives Allen a straightforward handle on the problem of the imperfective paradox (cf. section 5.2.3), namely by allowing an *event* to be an argument of the *OCCURRING* predicate (Allen 1984: 137):

- (324) (a) The ball fell onto the table
 OCCUR (FALL (ball, source, table), T)
 (b) The ball was falling to the table
 OCCURRING (FALL (ball, source, table), T)

This treatment comes very close to the way we described the relation between culminated processes and processes. As was described in chapter 4, Vendler's terminology disguised the fact that "accomplishments" like *fall to the table* or *walk to the station* are composite categories, consisting of a process associated with and leading up to a culmination point. The advantage of our approach is that it shows the principles underlying the relation between these categories (viz., in the aspectual network).

Allen's theory is less satisfactory. He states that there are 3 types of states of affairs (properties, processes and events) without explaining what their possible interconnections are. These three types are associated with intervals in different ways (properties *hold*, events *occur*, processes are *occurring*). Yet to give an account of the imperfective paradox, events are allowed as an argument of the *occurring* predicate. Although the intuitions behind this decision are clearly correct, it looks rather *ad hoc* in Allen's framework.

To conclude, it is clear that Allen's logic can be used as a specification of a database; its flexibility allows events to be entered into the database in any order, regardless of the order in which they actually occurred. An illustration of this can be found in the discussion of event relations in the narrative text example, where we explicitly treated events as updates to a database. Allen's general theory of action and time also has a fairly rich ontology which in certain respects resembles the aspectual taxonomy proposed in the previous chapters. However, the relations between the different categories are not stated clearly enough to allow for a principled approach to problems like the progressive or the perfect. The major problem is that, equating events with an interval leaves no room to talk about the internal structure of events or about how events are achieved (apart from a simple form of action decomposition used in Allen & Koomen 1983). And, apart from clustering events together when they have a common performing agent, it is hard to see how events (or, rather, intervals) can be grouped into more

complex structures - as we argued is essential for a proper treatment of some natural language phenomena. In general, little attention is paid to the actual mechanisms in natural language, and only a limited range of natural language phenomena can be dealt with in the theory.

8.3.3. Event-based ontologies

The proposals we have discussed so far acknowledged that there are a lot of problems attached to a situation-based world view, but it was ventured they would disappear by adding temporal features to the basic ontology. Kowalski & Sergot (1986), however, argue that most of the problems with the Situation Calculus are due to the ontological viewpoint itself: it is because the world is described as consisting of global situations that it becomes impossible to deal with simultaneous and partially ordered events, and that all relations that are not affected by an event have to be computed explicitly (the frame problem). Handling incomplete information about a situation as well as processing new information about past situations (as is typical in narrative processing or database updating) are equally cumbersome because of the global nature of situations.

In the formalism that Kowalski & Sergot develop, events are taken as the undefined primitives; the occurrence of an event implies the existence of time periods over which certain situations hold. Thus, an event description like *John was promoted from the rank of lecturer to the rank of professor* implies that there was a period of time, ended by this event, during which John had the rank of lecturer; and there is a period of time, started by the event, during which John has the rank of professor. Schematically, such an ontology can be represented as follows:

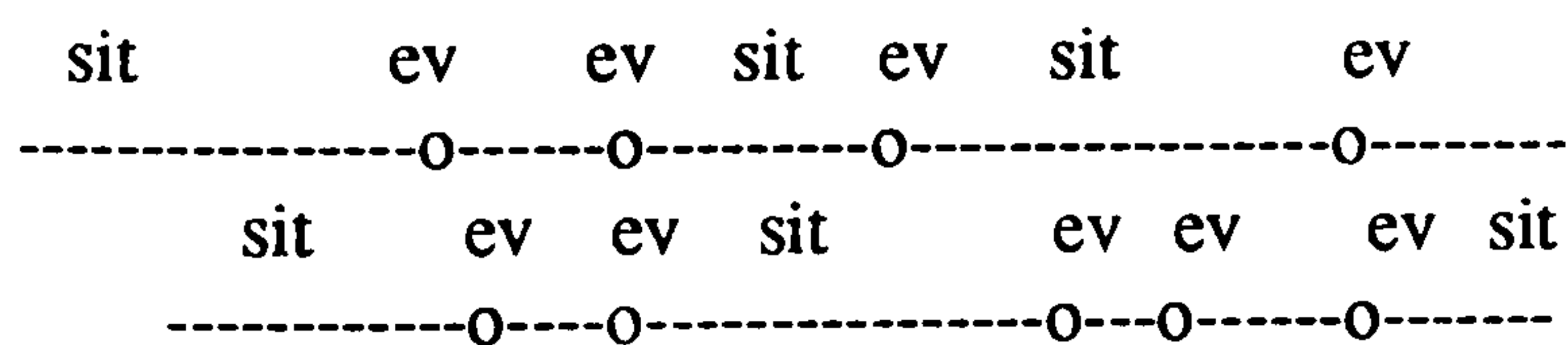


Figure 9: The ontology of the event calculus.

Kowalski & Sergot describe a formalism in first order predicate logic for the representation of and reasoning about events as in Figure 9 and their associated time structures. The calculus contains a number of rules that define how situations (and their time periods) can be associated with particular events. This calculus is expressed in Horn clauses, with the added principle of negation as failure. It is therefore executable as a logic program.

One of the advantages of this type of event calculus is that event descriptions do not have to be processed in the order in which the events actually occurred. This means that it is easy to process new knowledge about past events, and to work with hypothetical possibilities for the future. The calculus also allows for the possibility that events are not actually dated, but just ordered relative to other events. This is crucial for any event calculus that wants to deal with natural language phenomena. And because events are clearly distinguished from the associated time periods, representing simultaneous events does not pose any problems any more.

On the whole, the event calculus is a very flexible general purpose language that can be used for planning (cf. Sadri 1985), database updating and querying, as well as for natural language processing. Although it does not contain all the machinery that will be needed to deal with an extended fragment of language, its underlying ontology is such that an extension of the calculus is easy to envisage.

In the database literature, a very similar ontology was proposed by Lee, Coelho & Cotta (1985) for the construction of business databases. They developed a system for representing time dependent information which, like the event calculus, takes events as primitives and from these event descriptions derives the existence of certain properties. The formalization they present is primarily first-order classical logic and has been implemented in PROLOG. A crucial difference between the two formalisms is that in Lee's formalism events are identified by specifying their times, whereas in the event calculus they can be uniquely identified independent of their time of occurrence. For the processing of natural language text where events are described quite often without having a particular date associated with them, the latter option is clearly more desirable.

An obvious extension that is needed to Kowalski's event calculus is that we want to be able to deal with more than just punctual events. A simple yet efficient way of accomplishing this is by representing extended events as consisting of two Kowalski-like punctual events, one indicating the starting point of the event, the other its ending point. Such an approach has been suggested by various authors (McDermott 1982, Steedman 1982, Guenther et al. 1983, Guenther 1984) and forms the basis of the Time Map Manager (Dean & McDermott 1987). The Time Map Manager manages temporal relations as a network in which the nodes are instants of time associated with the beginnings and endings of events; the edges are labelled with upper and lower bounds on the distance between these points in time. Just as is the case in the event calculus, the existence of a punctual event implies that a certain situation becomes true. The

Time Map Manager engages in default reasoning of the type that a state of affairs is believed to be true throughout an interval if there is a punctual event, situated before the interval, that starts that state of affairs, and the state of affairs cannot be shown to end before the end of the interval. This form of reasoning is non-monotonic since later constraints may change the validity of this conclusion.

No work has been done to date to link up this type of temporal reasoning system with a natural language component. The work done by Harper (1986, & Charniak 1986) uses McDermott's (1982) point logic to handle temporal connectives, aspect and certain temporal adverbials, but only as a system for ordering the events talked about in a text. Events are represented as simple stretches of time, and McDermott's logic is used to derive conclusions about the way these time stretches are linked up to each other. As was argued in the previous chapters, trying to link the semantics of temporal categories in language to a structure that represents events as points or intervals on a time line will lead to avoidable complications in that semantics. Thus, a perfect like

(325) John had left at 3

is handled in Harper's framework by stipulating that the end of the time period associated with the event of leaving is situated before 3 o'clock. It follows that the perfect in (325) cannot be distinguished from the temporal expression in (325'), making this not really accurate as an account of the semantic import of the perfect:

(325') John left before 3 o'clock.

Harper's account does go beyond traditional interval-based accounts. She clearly recognizes that the fact that an event has endpoints associated with it "need not imply the achievement of the purpose with which the event was initiated" (Harper 1986: 6), thus making a distinction which will play an important role in the implementation to be presented in the next section.

No further work has yet been done to use Dean's Time Map Manager in a language understanding system, useful though it would be to be able to reason about how long events talked about in a text typically last. The implementation to be offered in the next section does not pertain to forms of default reasoning or sophisticated forms of constraint propagation in the temporal domain; at the same time, nothing in that implementation is incompatible with Dean & McDermott's program.

A shortcoming of the formalisms described in the previous paragraphs is their lack of other than temporal relationships between the events. However, recent work in Artificial Intelligence

has been involved with the modelling of events, taking into account the way events are structured into more complex entities, and taking into account causal as well as temporal relationships between them. The best worked out event-based model to date is Lansky's (1985, 1986). The formalism she presents is based on GEM (Lansky & Owicki 1983), a tool for concurrency specification and verification that reifies events and explicitly represents both their causal and temporal relations. The problem of synchronizing events in a parallel domain is handled in a first-order temporal logic. GEM also provides mechanisms for structuring events into so-called "locations of activity", and these in turn can be grouped together in various ways. The boundaries on these locations of activity are boundaries of causal access; this in essence means that two events with no causal relation between them cannot belong to the same location of activity - as in our episodes.

In Lansky (1986), the GEM tool is used to build event-based knowledge representations for use in planners. She suggests the use of three accessibility relations: temporal precedence, causality or consequentiality, and simultaneity. These relations, which are also part of the implementation offered in the next section, have the following properties:

precedence:	irreflexive, antisymmetric, transitive
causality:	irreflexive, antisymmetric, intransitive
simultaneity:	reflexive, symmetric, transitive

By following Lansky in making the contingency relation intransitive, it is possible to avoid certain problems in the treatment of *when*-clauses and perfects. These are the problems that arise because the search for possible consequences of an event has to be restricted to the *first* event in the chain of contingencies. Thus, when (326a) and (b) are asserted, it would be wrong to infer (c):

- (326) (a) When John left, Sue cried.
 (b) When Sue cried, her mother got upset.
 (c) When John left, Sue's mother got upset.

It should also be noted that the notion of causality proposed by Lansky and used in the implementation to be offered shortly is weaker than that used in other representation schemes (for example that of McDermott 1982) in that contingency is here decoupled from eventuality: if an event A stands in a contingent relation to an event B, then an occurrence of A will *not* automatically lead to an occurrence of B: a student sending a draft of a dissertation to his supervisor is a prerequisite for or enables the supervisor to write lots of detailed comments but does not "cause" this to happen in the more traditional sense of the word and does not automatically or inevitably lead to the supervisor doing this.

8.3.4. Conclusion

The representational formalisms presented in the previous sections mark a drastic change in the way people have been thinking about representing time-related knowledge. Where the world used to be viewed as a series of snapshots altered by events, and domain activity was defined in terms of its state-changing function, the world is now viewed as a web of interrelated events, and the changing state of the world as well as the very notion of time are byproducts of these more basic ontological properties. In planning, for example, it was typically thought that many problems would disappear once a solid temporal logic had been developed that allowed for accurate reasoning about the temporal order between events. Recent planning systems suggest, however, that a better modelling of "cause and effect" relations between events would aid in the design of better planning techniques (Drummond 1984). This is not to say, obviously, that time never plays a role in planning systems. Especially for plans where tasks have to be performed within certain real time constraints (rather than being ordered in a particular way because of the consequent states they cause), time handling is important. Vere's DEVISER (1981, 1984) or Bell & Tate's "Open Plan Architecture" (1985) both allow the explicit representation of time constraints for goals or actions. But this is quite a different problem, one where time is a resource the planner has to handle, just as it sometimes has to take into account other types or resources (e.g. maximum cost of actions, scarcity of objects, ...).

In previous chapters I tried to show that, for an adequate semantics of temporal phenomena in natural language, a somewhat complex ontology has to be presupposed. In this chapter I have tried to indicate that, however unusual this ontology may look, it looks remarkably like representation models developed independently in Artificial Intelligence, sometimes for totally different reasons. In the next section I will show that the episodic ontology proposed here can be implemented, using Kowalski-like events as basic entities to represent both punctual as well as extended events along the lines suggested by Dean & McDermott, and using Lansky's causality relation to represent the consequential links between events.

8.4. An implementation of the episodic representation scheme

8.4.1. Introduction

In the previous chapters, a conceptual analysis was offered of the way temporally referring expressions in language operate. It was claimed that a principled temporal semantics is possible on the assumption that the categories of tense, aspect, aspectual adverbials and of propositions themselves refer to a mental representation of events that is structured on other than purely temporal principles, and to which the notion of a nucleus or a consequentially related sequence

of preparatory process, goal event and consequent state is central.

In the earlier sections of the present chapter it was claimed that the identification of the ontology involved in the process of temporal reference is also a vital preliminary to the construction and management of temporal databases. For a database containing information about events to be accessible by means of natural language, a more complex knowledge structure is needed than one which merely represents the history of events as a single time-line. It will have to consist, rather, of several time-lines, each associated with a single "causally" or consequentially related sequence of events (episodes) leading to the satisfaction of a particular goal or intention. Each of these events has associated with it (parts of) a nucleus, indicating that previous events within the episode are part of the preparatory process, and that consecutive events within the episode constitute the consequences. These episodes may from time to time intersect or diverge, and may be nested within one another. The nested sequences will then represent steps undertaken to achieve a sub-goal of the higher sequence.

For an implementation of these ideas a database was set up in which the information was organized around these principles. It is represented pictorially as in Figure 10. It tells the story of how Mary goes to Maxies one evening by taking the bus and walking the rest of the distance. When she gets there, John spots her and makes a phone call to his friend Luke. Luke then breaks into Mary's house, but sets off the alarm and is arrested by the police. They phone Mary, who interrupts her dinner.

The program is designed to answer questions about the events in this database, questions involving the use of the various temporal expressions described in chapters 5 and 6. Before analyzing the exact workings of this program, let us first consider its desired behaviour. Note that, for ease of exposition, examples in this preliminary discussion sometimes contain personal pronouns and various punctuation devices which are not part of the actual implementation - as will emerge from the sample sessions to be discussed shortly. Actual examples from the program will be preceded by a >>-sign.

In the world of Figure 10, the question

(327) When John noticed Mary, did he phone Luke?

should be answered positively, since both events did indeed occur and, moreover, stand in a contingency relation as required by the *when*-connective. Similarly, the question

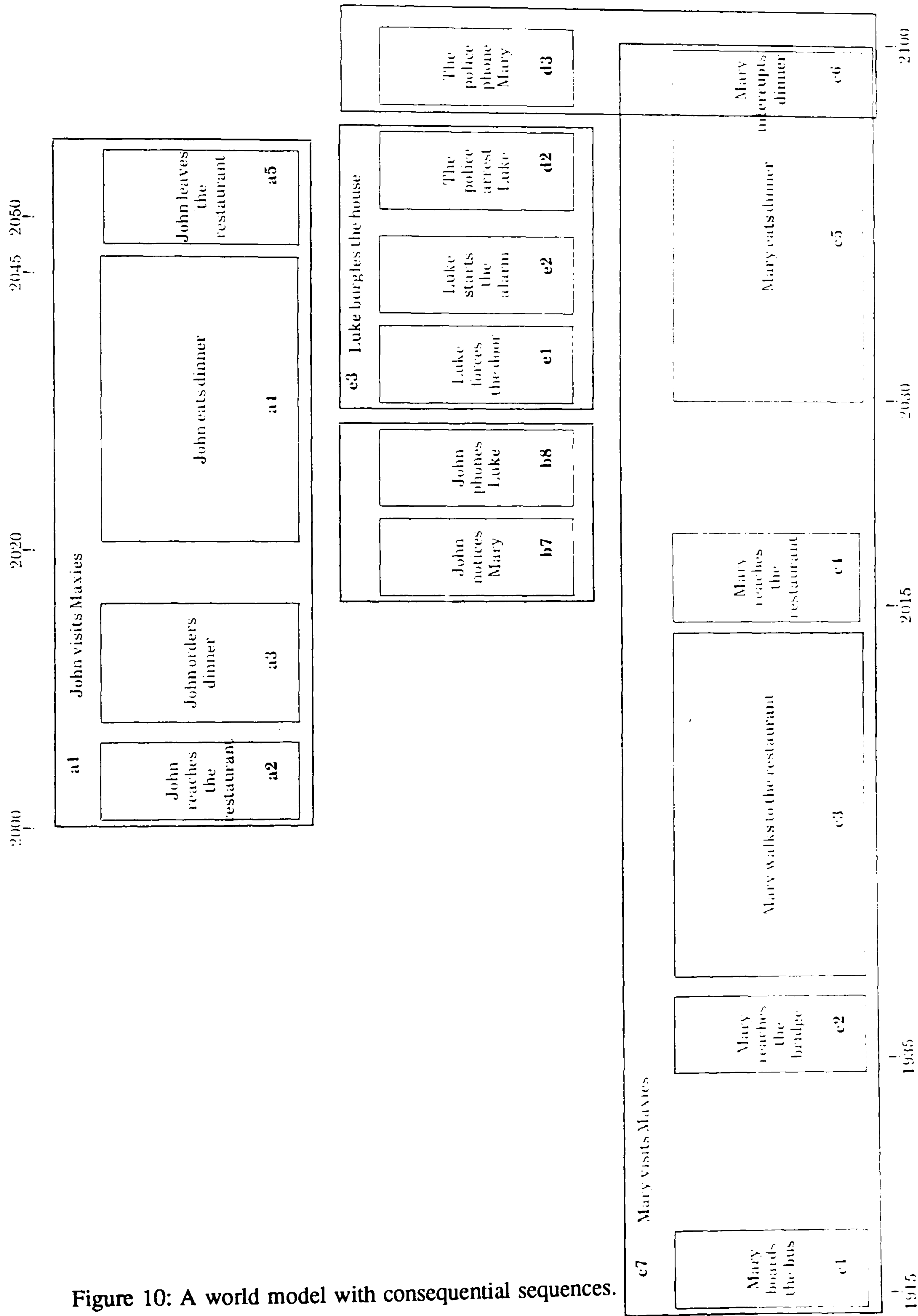


Figure 10: A world model with consequential sequences.

(328) When Luke burgled the house, did he force the door?

should be answered with a "Yes", since *Luke burgling the house* is an event which can be decomposed into its constituent parts, one of which is forcing open the door.

However, the answer to a question like

(329) When Mary reached the bridge, did she eat dinner?

should be negative: although both events did occur and form part of the same episodic sequence, there is no direct contingency link between these events. As was argued in the previous section, contingency is not a transitive relation in the ontology used here. And (330) should also be answered negatively:

(330) When John ordered dinner, did Mary reach the restaurant?

Although both events happened at approximately the same time, they do not have the required consequential link between them.

Since no consequential connection is required between the events described in a *when*-clause and a stative main clause, the following question should be answered positively:

(331) When Luke started the alarm, was Mary eating dinner?

The program need only check whether the two states of affairs really occurred, and whether the first one is temporally contained in the second one. Note also that, although it is true that *Mary was eating dinner*, at certain points during the history under discussion, it doesn't follow from that that there is a later point at which she has eaten dinner: Mary's dinner is an example of a culminated process the culmination of which is never reached.

As for the perfect, the program should answer with "Yes" the question

(332) Had John eaten dinner at 2050?

since the episode of which *John eating dinner* is a part is not over yet at that point in time. It should, however, answer negatively the question

(333) Had Mary eaten dinner at 2100?

The reason for this lies in the fact that a perfect refers to the consequences associated with a culmination point. However, in the history under discussion Mary never actually reaches the culmination or goal of finishing dinner because of the unexpected phone call. Because of this, no consequences can be associated with it, and the query in (333) will be answered negatively.

It is because of this absence of a culmination point that the program should also answer with "No" the query

(334) Did Mary eat dinner in 30 minutes?

John, however, did achieve the goal of finishing dinner. Because of this, the program can confirm as true the question

(335) Did John eat dinner in 25 minutes?

In both these cases, a more elaborate reply than a mere "yes" or "no" would be helpful. Since this involves complicated issues of intention recognition on the part of the system, no attempts were made in this implementation to accomplish this.

Finally, since *in*-adverbials in association with culmination expressions typically describe the length of the preparatory process leading up to that culmination event, the program should also reply with a "Yes" to a question like

(336) Did Mary reach the bridge in 20 minutes?

This can be done by looking at whatever preparatory process it can find leading up to Mary's reaching the bridge and measuring the time span associated with that preparation.

The program is only intended to illustrate that it is feasible to incorporate in a database the ontological principles outlined in the previous chapters, and to demonstrate how that database can be accessed by means of natural language queries. Although the queries discussed in the next section sometimes sound unnatural, this is a result of the limited capacities of the parser rather than being a result of the aspectual theory implemented in the program: a question like

(337) >> when mary visited maxies did mary reach the restaurant in 60 minutes

would undoubtedly sound better as

(338) When Mary visited Maxies, did it take her an hour to get there?

However, as was pointed out in chapter 5, an expression like *it took...an hour* has the same function vis-à-vis the temporal structure of a discourse as does an *in*-adverbial. It follows that as far as the program is concerned (337) and (338) would result in exactly the same verification procedures to be carried out in the database.

8.4.2. The database

The implementation of these ideas was carried out by using some of the techniques discussed in the previous section.

First, as was pointed out with respect to Kowalski's event calculus, it is desirable for a system like the one under discussion that events can be identified independent of the time at which

they occurred. To this end, each event is given a unique identifier, as in (339). These identifiers also show up in the pictorial representation in Figure 10.

```
(339)  event(visit(john,maxies), a1).
        event(eat(john,dinner), a4).
        event(arrest(police,luke), d2).
```

Note that, as far as this identification is concerned, no distinction is made between episodes and events. Thus, although John's visit to Maxies is decomposable into subevents, it is given an identification just like any other event. Differences between events and episodes will, obviously, emerge elsewhere in the program.

In the previous section, whilst discussing Dean's work on the Time Map Manager, it was argued that an ontology using punctual events can also be used to handle extended events, viz. by referring to their starting and ending points. The situation in the ontology presented here is slightly more complicated in that we want to be able to distinguish between extended events that culminate (culminated processes) as opposed to those that merely stop (processes). A culminated process expression like

```
(340)  event(eat(john,dinner), a4)
```

will therefore have a **start(a4)** and a **cul(a4)** associated with it, whereas Mary's interrupted dinner (**c5**) only gets a **start(c5)** and a **stop(c5)**. It is important to keep in mind that these data are supposed to be data extracted from natural language descriptions, and that classifying something as a process or as a culminated process is not a real world distinction but depends on the way these events were described. I will return to this point when discussing how the program handles imperfective uses of the progressive.

In the section on Lansky's work, some of the accessibility relations that govern the organization of the basic entities in this model were already introduced. First, a notion of contingency is needed which forms chains of consequentially related events. Since, as was discussed before, this relation is not a transitive one, the constituent parts of an episode can be given indirectly, i.e. by stating pairwise consequential links between events. As a reminder that this relation is akin to but should not be confused with the one that we normally think of as causal (because it is an intransitive relation decoupled from eventuality, cf. section 8.3.3) it will be referred to as **bcause**:

```
(341)  bcause(a2, a3).
        bcause(a3, a4).
```

A simple procedure can be invoked to find which events belong to the same episode: an event with identification **IdA** forms part of the same consequential chain as event **IdB** if **IdA**

bcauses **IdB**, or if **IdA** stands in the bcause relation to some other event which is in the same episode as **IdB**:

```
(342)  same_episode(IdA, IdB) :-
        bcause(IdA, IdB).
        same_episode(IdA, IdB) :-
        bcause(IdA, IdX),
        same_episode(IdX, IdB).
```

A second accessibility relation is the one that holds between an episode and its constituent events. As was remarked earlier on, as far as the database is concerned there is no real difference between events and episodes, since episodes are merely events about the internal structure of which we happen to have some more information. A device is therefore needed that will help us keep track of what events constitute which episode. This relation will be referred to as **dominate**:

```
(343)  dominate(e3,e1).
        dominate(c7,c1).
```

One could enumerate domination relations like these for every event in an episode. Thus, for

```
(344)  event(visit(john,maxies), a1)
```

one could list in the database

```
(345)  dominate(a1, a2).
        dominate(a1, a3).
        dominate(a1, a4).
        dominate(a1, a5).
```

However, since we already know that the events in the episode are bcausally related, there is some redundancy in this strategy. It seems like the database need only contain a mention of a domination relation between an episode and its first event, plus a rule stipulating that an event called **IdA** dominates an event **IdB** if **IdA** dominates some other event which is in the same episode as **IdB**:

```
(346)  dominate(IdA, IdB) :-
        dominate(IdA, IdX),
        same_episode(IdX, IdB).
```

The other accessibility relations in the database are the standard simultaneity and earlier_than relations. No great use is made of these in the current implementation. As in Kowalski's event-calculus, any or all of the events in the database may be associated with absolute time. For example:


```
(347)  occur(cul(a2), 2000).
        occur(start(c5), 2030).
```

The simultaneity relation can then simply be defined as two events occurring at the same time.

```
(348)  simult(A, B) :-
        occur(A, TimeA), occur(B, TimeB),
        TimeA = TimeB.
```

The `earlier_than` relation is defined to hold between two events that are causally related, or between events that have times associated with them, one of which is earlier than the other. Transitivity is taken care of by means of the recursion in the last clause.

```
(349)  earlier_than(A, B) :-
        occur(A, TimeA), occur(B, TimeB),
        TimeA < TimeB.
earlier_than(A, B) :-
    bcause(A, B).
earlier_than(A, B) :-
    (bcause(A, X), earlier_than(X, B);
     earlier_than(A, X), bcause(X, B)).
```

In a full-fledged implementation with real temporal reasoning capabilities, the definitions for simultaneity and `earlier_than` will necessarily be somewhat more complicated. Part of the reason for this lies in the nature of PROLOG. As far as the theory is concerned, there is no real difference between an event occurring at a particular *time*, or an event being simultaneous with another *event*. Similarly, it is possible to assert both that an event occurred before a particular time or before another event. This is because events as well as absolute times can be temporal referents, simultaneous with which or before which another event occurs.

If this idea is carried over into a PROLOG program without any adjustments, then the program might at a certain point try to prove that an event, say `x5`, is earlier than a time, say `1325`, by means of the comparison operator `<`. However, to answer a query like `A < B`, `A` and `B` are evaluated as arithmetic expressions; the goal fails if `A` or `B` are not arithmetic expressions, and an error condition results if `A` or `B` are not ground.

Because of this, definitions in PROLOG for the simultaneity and `earlier_than` relations will be more complex than they are in the program discussed here, clearly separating reference times from reference events. For the application under consideration, nothing important follows from this.

To summarize, the database consists of a description of the events it knows about. Each event description has associated with it a unique identifier. The database furthermore contains

information about the aspectual characterization of these events, in terms of information whether events culminate or stop. Any or all of these events may have a time associated with them; events may be mentioned in the database which did not occur, or which did occur but for which no accurate time of occurrence is known. Finally, to keep track of which events belong to which episode, events can be pairwise linked in terms of an (intransitive) bcausal relation; a domination relation gives information of how an episode can be decomposed into its constituent events.

The complete database, corresponding to Figure 10 and used in the discussion of the implementation in the next section, is given in (350):

(350)

%identification of known events:

event(visit(john, maxies), a1).	event(arrest(police, luke), d2).
event(burgle(luke, house), e3).	event(phone(police, mary), d3).
event(visit(mary, maxies), c7).	event(board(mary, bus), c1).
event(reach(john, restaurant), a2).	event(reach(mary, bridge), c2).
event(order(john, dinner), a3).	event(walk(mary, restaurant), c3).
event(eat(john, dinner), a4).	event(reach(mary, restaurant), c4).
event(leave(john, restaurant), a5).	event(eat(mary, dinner), c5).
event(notice(john, mary), b7).	event(interrupt(mary, dinner), c6).
event(phone(john, luke), b8).	event(force(luke, door), e1).
	event(start(luke, alarm), e2).

%causality relations:

bcause(a2, a3).	bcause(b8, e3).	bcause(c1, c2).
bcause(a3, a4).	bcause(e1, e2).	bcause(c2, c3).
bcause(a4, a5).	bcause(e2, d2).	bcause(c3, c4).
bcause(b7, b8).	bcause(d2, d3).	bcause(c4, c5).
	bcause(d3, c6).	

%starts of episodes

dominate(e3, e1).
dominate(c7, c1).
dominate(a1, a2).

%time data and aspectual characterizations

occur(cul(a2), 2000).	occur(cul(c1), 1915).
occur(start(a4), 2020).	occur(cul(c2), 1935).
occur(cul(a4), 2045).	occur(start(c3), 1935).
occur(cul(a5), 2050).	occur(cul(c3), 2015).
occur(start(b8), 2030).	occur(cul(c4), 2015).
occur(cul(e2), 2040).	occur(start(c5), 2030).
occur(start(e3), 2035).	occur(stop(c5), 2100).
occur(stop(e3), 2055).	occur(cul(c6), 2100).

8.4.3. Aspect and aspectual adverbials

The basic action of the program is to take the input question and pass on to the database a representation of its meaning together with the request to check whether the question should be answered with a "yes" or a "no". No attempt is made to give more helpful answers that involve intention recognition on the part of the program. The program also does not add or change information in the database; it can only be used to answer yes/no questions.

To achieve this, the program includes a rather trivial and for present purposes unimportant DCG-based parser. For each clause it passes on to the database a formula containing information about the tense in the clause (past or present), its aspectual class (progressive, perfect, or simple), a representation of the event talked about, the type of temporal adverbial involved (if any) and the argument of that adverbial. The data for each clause are given as elements in a list, separated by commas. For example:

```
(351)  >> did john eat dinner in 25 minutes
        check((past,simple,eat(john,dinner),in,25)).

        >> has john phoned mary
        check((present,perfect,phone(john,mary))).
```

In the case of complex questions, the formula passed onto the database also contains a mention of the connector involved. It is separated from the clauses by means of a semicolon, which also separates the clauses themselves:

```
(352)  >> when luke started the alarm was mary eating dinner
        check((when;past,simple,start(luke,alarm);past,progressive,eat(mary,dinner))).
```

The use of lists to represent this information was decided on because it makes for greater readability. Care should be taken not to think of the semicolons in these lists as operators.

In the following paragraphs, I will first discuss the way the program deals with aspect and aspectual adverbials. In this discussion, the role of tense will be ignored. However, tense *does* play a role in this system, reflecting its anaphoric nature. As can be seen in (351) and (352), the formulae the parser passes on to the database contain a mention of the tenses of the clauses that make up the questions. This tense information will be used to determine a temporal referent with respect to which the query is to be interpreted. The precise mechanism by which this is done will be discussed in the next section.

To answer a question the program carries out a check procedure of the type given in (351) and (352). It is at this point that the aspectual network starts doing its work.

As was argued in chapter 7, following on from a point made by Dowty (1986), the aspectual classification of a sentence is something which can only be decided on at the level of model-theoretic interpretation, not at the level of syntax or at an intermediate level between syntax and semantics. To reflect this theoretical point, the transitions of the aspectual network were implemented as a set of inference rules the database manager can use to prove or disprove a query against its database.

As a result, the basic procedures for checking the truth of an expression are fairly straightforward: a progressive, for example, is true at a point in time if its basic proposition describes an event of the process variety, and if the time asked about is situated in between the times associated with the starting and ending points of that process:

```
(353)  check((progressive, A, at, Time)) :-
        event(A, IdA),
        process(IdA, Time1, Time2),
        Time1 =< Time, Time < Time2.
```

Thus, after processing a query like

```
(354)  >>was mary eating dinner at 2045
```

the parser sends to the database manager the request

```
(354') check((past, progressive, eat(mary,dinner), at, 2045)).
```

To prove (354'), and ignoring the role of tense, the program first checks whether it has any information about a state of affairs that can be described as *eat(mary, dinner)*; it finds such an event in **c5**. Next, it checks whether that state of affairs is a process, possibly with starting time **Time1** and ending time **Time2**. To accomplish this goal, the first rule it tries is (355), which merely involves checking the database to see whether it knows about a point at which the state of affairs started and one where it stopped:

```
(355)  process(IdA, Time1, Time2) :-
        occur(start(IdA), Time1),
        occur(stop(IdA), Time2).
```

In the case of **c5**, it will find

```
(355') occur(start(c5), 2030).
        occur(stop(c5), 2100).
```

and conclude that **c5** is indeed a process, starting at 2030 hrs and ending at 2100 hrs. Returning to (353), the program then checks whether the time asked about (2045 hrs) is included in that time span. Since this is the case, the question will be answered positively.

It is important to realize that the search procedure *event(A,IdA)* in (353) does not jeopardize

the account given in chapter 5 of the imperfective paradox. Consider again example (354). The database is searched for information about an event called *eat(mary,dinner)*. As was pointed out in the previous section, from the fact that information about such an event is found in the database, it does not follow automatically that that event actually took place. Only in the next step, when searching for start and end points, does the occurrence of the event come into question. And, in this case, it turns out that there is no culmination point - hence, the event referred to as "Mary eating dinner" is not a culminated process.

A query like

(356) >>was john leaving the restaurant at 2048

results in a request for verification to the database manager of exactly the same type as in the previous example:

(356') check((past, progressive, leave(john,restaurant), at, 2048)).

The first step in the verification is, again, a search in the database for an occurrence of the event, in this case *leave(john, restaurant)*. Such an event is found, labelled a5. The program then checks whether that event is a process, by looking for a *start(c5)* and a *stop(c5)*. Since it only finds a culmination, a rule will be invoked to turn this culmination into a process. This is done by finding an event of no matter what aspectual type which precedes *cul(c5)* and which forms part of the same episode. In the example under discussion, *cul(c4)*, i.e. the point where he finishes his dinner, is an appropriate candidate. Once such an event is found, the program knows there is a preparatory process leading up to *cul(c5)* which started at least as early as the time associated with *cul(c4)*. This is what is expressed in (357):

(357) process(IdA, Time1, Time2) :-
 occur(cul(IdA), Time2),
 cause(IdB, IdA),
 occur(any(IdB), Time1).

The result of this procedure is that a process is found for *leave(john, restaurant)* which starts at 2045 hrs (the time he finished his dinner) and ends at 2050 hrs (the time he actually left). The main rule for checking the validity of a progressive then checks whether the time asked about (2048 hrs) is situated somewhere within that period.

Again, *leave(john,restaurant)* need not have occurred for (356) to be answered positively. If at some stage during the construction of the database the information had been added that *John was leaving the restaurant at 2048*, then an event description *leave(john,restaurant)* would have been added to the database, but no occurrence of a culmination would have been added for this event. A later query whether John was leaving the restaurant at that time would still

be answered positively, even though no information about whether he actually did leave the restaurant is available. This conforms to the account of the imperfective paradox given in section 5.2.3.

Note also that in (357), establishing the preparatory process is restricted to finding the immediately preceding event on the consequential chain. Without this restriction, the program would accept as true a statement like

(358) John was leaving the restaurant at 2000

where 2000 hrs is actually the time he *arrived* at Maxies. Restricting the search for preparatory events like this may seem like an *ad hoc* feature of the program. In the same way that John ordering dinner and John eating dinner were treated as two separate events, so John asking for the bill, paying it and asking for his coat could also have been treated as separate entities in the database. In that case, all these events can be regarded as preparatory to his leaving, and search should not be restricted to the one immediately preceding. However, this point merely illustrates the importance of the episodic representation: if we did have information about John paying the bill, leaving a tip and asking for his coat, these events would have to be stored as part of event (or subepisode) a5, i.e. as events making up the more complex event of John leaving the restaurant. The event a5 would at that point not just have a culmination point associated with it, but also a start. Checking whether a progressive description of that event is true with respect to a point in time would be a straightforward application of the same rules used for checking whether *John was eating dinner* is true at a particular point in time.

Moreover, suppose we do have information about the fact that John settles the bill and asks for his coat but then, unfortunately for him but conveniently enough for our present purposes, collapses and dies. There would still be an event, called *leave(john,restaurant)* dominating the events of John settling the bill and asking for his coat, and having associated with it a start and a stop. The progressive can still be used to refer to that event; although the program will confirm as true that *John was leaving the restaurant* at a particular point in time, it will reject that he has actually left it.

This account, I think, reflects fairly accurately the way we think about preparatory processes. We have a clear idea about what constitutes the event of leaving a restaurant, for example when asserting

(359) John was leaving the restaurant (when the bomb exploded).

Similarly, we know how to answer a question like (360):

(360) How long did it take John to leave the restaurant?

In both cases, a particular unique preparatory process seems to be available for identification. The decision which events are part of it and which ones are not is dependent on our general world knowledge or discourse-specific knowledge about what constitutes a leaving-the-restaurant event. This knowledge has to be incorporated in episodic fashion in a system like this.

For the verification of questions containing *in*-adverbials the general rule in (361) is invoked:

(361) `check((simple, A, in, Time)) :-
 event(A, IdA),
 cp(IdA, Time1, Time2),
 span(Time2, Time1, Time).`

This rule says that a question in the simple past involving an *in*-adverbial can be answered with a "yes" if the event talked about is a culminated process (abbreviated to *cp*), the time span of which is the time given by the adverbial. Thus, a question like

(362) `>>did john eat dinner in 25 minutes`

causes a search in the database for an occurrence of the event *eat(john, dinner)*. The program then checks whether this state of affairs is a culminated process, starting at a time *Time1* and culminating at a time *Time2*, since only if world knowledge supports this fact is combination with the *in*-adverbial felicitous. The simplest way of checking whether something is a culminated process is by searching for a *start* and *cul* point associated with the event. In the case of John's dinner such points are found. The next step in (361) is then to verify whether the time span between these two points equals the time given in the *in*-adverbial. This is basically just a matter of subtracting the starting time from the culmination time, with a possible adjustment to convert the 100-based time system in the database to our normal 60-based time line (i.e. the time that elapsed between 1900 hrs and 2000 hrs is not 100 minutes but only 60 minutes).

An *in*-adverbial combined with a culmination expression, as in

(363) `>>did mary reach the restaurant in 60 minutes`

will be translated into a similar request as for the previous example:

(363') `check((past,simple,reach(mary,restaurant), in 60)).`

For this to be true, the program will have to prove that *reach(mary,restaurant)* is a culminated process. Since it only finds the occurrence of a culmination point for this event, a rule is triggered that examines whether the context allows for a transition from culmination to culminated process:

```
(364)  cp(IdA, Time1, Time2) :-
        occur(cul(IdA), Time2),
        addprocess(IdA, IdB),
        occur(any(IdB), Time1),
        nl, write('Looking at the preparatory events here.').
```

As was discussed in the previous chapters, a culmination can be turned into a culminated process if the context allows a preparatory process to be added to the culmination. The function `addprocess(IdA, IdB)` does exactly that. It takes the event with identification label `IdA` and then searches for all events that form part of the same episode as `IdA` and precede it. In example (363), it will eventually find the event of Mary boarding the bus, which did happen 60 minutes before she reached the restaurant. While searching the preparatory process a message is printed out acknowledging this. This is done to keep track of the two readings that can be associated with a sentence like (362): one where the eating itself took 25 minutes, and one where the eating event is itself taken as a culmination in its own right and the *in*-adverbial describes the length of the period leading up to it.

For-adverbials are treated in a similar way:

```
(365)  check((simple, A, for, Time)) :-
        event(A, IdA),
        process(IdA, Time1, Time2),
        span(Time2, Time1, Time).
```

First, the database is searched for an occurrence of the event talked about. Then it is checked whether this event is a process - as is required by this adverbial. The inference rules to accomplish this are the same as those discussed before for the progressive. For obvious reasons, the "stripping off" transition from culminated process to process is not carried out by removing the culmination point from the database; instead, a message signals the user that the culmination point is being ignored:

```
(366)  >> did john eat dinner for 25 minutes
        Ignoring the culmination point.
        Yes.
```

Checking whether the perfect of an expression still holds at a particular point in time involves searching the database for an occurrence of the state of affairs referred to and checking whether that state of affairs is a culmination expression or has a culmination expression associated with it which occurred before the time asked about. Next, a database search is carried out to check whether any consequences still held at the time talked about:


```
(367)  check((perfect, A, at, Time)) :-
        event(A, IdA),
        cul(IdA, TimeA),
        TimeA < Time,
        same_episode(IdA, IdB),
        simult(any(IdB), TimeB),
        Time =< TimeB.
```

If no culmination point is found, this is signalled to the user:

```
(368)  >> had john ordered dinner at 2020
        Yes.
```

```
>> had mary eaten dinner at 2100
        No culmination point known. Verification fails.
```

8.4.4. Anaphoric tense and when-clauses

It was argued in chapter 2 that tense is anaphoric in nature. A question containing a simple past, like

```
(369)  Did it rain?
```

does not talk about some arbitrary time in the past but refers, rather, to a previously established reference time.

This idea was also implemented in the system under discussion. As a result, a question like

```
(370)  >> did luke start the alarm
```

does not get an answer since no reference time was provided for the simple past tense to refer to. Such a referent can be provided by means of a *when*-clause, as in (371). Moreover, this referent then remains available for future reference, until a new referent is set up explicitly.

```
(371)  >>when luke burgled the house did luke force the door
        Yes
```

```
>>did luke start the alarm
        Yes
```

```
>>did mary eat dinner
        No
```

```
>>when mary visited maxies did mary eat dinner
        Yes
```

To achieve this, the program does not just give the database a representation of the question under consideration but also mentions whether there is a current temporal focus against which

the question is to be interpreted. The top-level processing loop of the program is given in (372):

```
(372)
start :-
    write('>> '),
    read_sent(Sentence),
    do(Sentence, TemporalFocus),
    continue(TemporalFocus).
continue(TemporalFocus) :-
    write('>> '),
    read_sent(Sentence),
    do(Sentence, TemporalFocus).
do(Sentence, TemporalFocus) :-
    parse(MeaningRepresentation, Sentence, []),
    check(MeaningRepresentation, TemporalFocus).
```

When starting the program, the >>-sign appears which means the program is ready to accept your question. The question the user types in is read by the program and then the goal `do(Sentence, TemporalFocus)` is executed. Execution of this goal consists of parsing the sentence, building up a meaning representation for it, and then passing on this meaning representation to be checked against the database taking into account the current temporal focus. When all this is finished the program continues with a temporal focus which is not necessarily the same as the previous focus: whilst satisfying the `check` goal, it is decided whether a new focus needs to be created or not.

The role this temporal focus plays in the program can best be illustrated by demonstrating the way the program handles questions involving *when*-clauses:

(373) >>when luke burgled the house did luke force the door

To answer this question, the program tries to satisfy the following goal:

```
(374) check((when; past,simple,burgle(luke,house);
           past,simple,force(luke,door)),TemporalFocus).
```

If the current temporal focus is different from the event described in the *when*-clause, then that event description may be discarded as the temporal focus and replaced by the event in the *when*-clause. Similarly if there is no temporal focus, as is the case here since we are at the start of the discourse, the event described in the *when*-clause will become the new temporal focus:

```
(374*) check((when; past,simple,A; past,simple,B), TemporalFocus) :-
        check((when; past,simple,A; past,simple,B), A).
```

This means that for (373), the event of Luke burgling the house becomes the new temporal focus for possible subsequent reference.

The verification of simple aspect sentences containing *when*-clauses can be executed in two ways:

(375) `check((when; past, simple, A; past, simple, B), A) :-
 event(A, IdA),
 event(B, IdB),
 bcause(IdA, IdB).`

`check((when; past, simple, A; past, simple, B), A) :-
 event(A, IdA), event(B, IdB),
 dominate(IdA, IdB).`

The first rule checks whether the events talked about stand in the appropriate bcausal relation. If this is not the case, the program tries to satisfy the next goal by checking whether the event described in the *when*-clause has constituent parts, one of which is the event described in the main clause.

A *when*-clause combined with a main clause containing a perfect or progressive auxiliary or any of the aspectual adverbials discussed in the previous section can be handled as straightforward combinations of the rules given before. Consider:

(376) `check((when; past, simple, A; past, progressive, B), A) :-
 event(A, IdA),
 occur(cul(IdA), Time),
 check((progressive, B, at, Time)).`

This rule checks whether there is information in the database about the *when*-clause event and, if so, the program checks at what time this event occurred. It then checks whether the progressive main clause was true at that point in time, using the same rules that were discussed before for progressives.

The role of tense should be clear now. A query like

(377) `>>did john eat dinner in 25 minutes`

is translated as

(377') `check((past,simple,eat(john,dinner),in,25)).`

This cannot be resolved with any of the check-procedures of the previous section since there is a tense in (377'), whereas the goals to be satisfied for aspectual adverbials and auxiliaries do not contain a mention of tense. The tense in (377') will then trigger an entirely different rule, viz. one which will establish the temporal referent against which the query in (377) is to be answered. Once this is resolved, and it is decided that the event of John eating dinner is part of the nucleus associated with the temporal focus, the rule for *in*-adverbials discussed in the previous section will come into play and check whether the event talked about in (377') is of

the right aspectual type and has the right length.

After processing a question like

(378) >>when luke burgled the house did luke force the door

the user can ask a question like

(378') >>did luke start the alarm

Since the current temporal focus is *burgle(luke, house)*, the check call that results from (378') will be

(379) check((past,simple,start(luke,alarm)), *burgle(luke,house)*).

Checking whether the question in (378') should be answered with a "yes" in these circumstances is similar to trying to answer the question

(378'') When Luke burgled the house, did he start the alarm?

The check procedure in (379) will therefore be treated as if it was a question containing a *when*-clause, where the temporal focus serves as the subordinate clause. This event description also remains the temporal focus for possible future use. This is expressed in rule (380):

(380') check((past, AnyAspect, A), B) :-
check((when; past, simple, B; past, AnyAspect, A), B).

For (379), this will result in an attempt to satisfy the following goal:

(379') check((past,simple,*burgle(luke,house)*;
past,simple,start(luke,alarm)); *burgle(luke,house)*).

The query will be answered with a "yes" since there is an appropriate relation between the two events (viz. a domination relation). The event of Luke burgling the house is kept as the temporal focus for possible future reference.

8.4.5. Program and sample session

What follows is a complete listing of the program, except for the parser.

1. The aspectual auxiliaries and adverbials:

- a progressive holds if core event is process expression surrounding the time asked about:

check((progressive, A, at, Time)) :-
event(A, IdA),
process(IdA, Time1, Time2),
Time1 =< Time, Time < Time2.

- a perfect holds at a Time if its core event is of the type "culmination", and the consequences associated with the core event are still in force at the time asked about:


```

check((perfect, A, at, Time)) :-
    event(A, IdA),
    cul(IdA, TimeA), TimeA < Time,
    same_episode(IdA, IdB),
    occur(any(IdB), TimeB),
    Time =< TimeB.

```

- a *for*-adverbial only combines with a process expression; its time-span has to be that expressed in the adverbial:

```

check((simple, A, for, Time)) :-
    event(A, IdA),
    process(IdA, Time1, Time2),
    span(Time2, Time1, Time).

```

- an *in*-adverbial only combines with a culminated process expression; its time-span has to be that expressed in the adverbial:

```

check((simple, A, in, Time)) :-
    event(A, IdA),
    cp(IdA, Time1, Time2),
    span(Time2, Time1, Time),
    write('It is the right amount of time. ').

```

- the time-span is calculated by converting the 100-based time-system to the 60-minute hour:

```

span(Time2, Time1, Time) :-
    (Time2 - Time1 == Time ; Time2 - Time1 - 40 == Time).

```

2. The treatment of *when*-clauses and the role of the temporal focus:

- a complex question containing the *when*-connective and two simple past clauses will be answered with "yes" if they stand in the appropriate causal relation, or if the *when*-clause describes an episode of which the main clause forms a part; otherwise, the answer is "no", but the *when*-clause event does remain the current temporal focus; the two possible outcomes, resulting in either a "yes" or a "no" are separated by means of the ;-predicate:

```

check((when; past, simple, A; past, simple, B), A) :-
    event(A, IdA), event(B, IdB), !,
    ((because(IdA, IdB); dominate(IdA, IdB)),
    nl, write('Yes.'), nl, continue(A);
    nl, write('No'), nl, continue(A)).

```

- the verification of a question containing a *when*-clause combined with a main clause containing a progressive or perfect auxiliary (referred to as *OtherAspect*) or an aspectual adverbial involves a combination of the rules given above:

```

check((when; past, simple, A; past, OtherAspect, B), A) :-
    event(A, IdA), occur(any(IdA), Time),
    (check((OtherAspect, B, at, Time)),
    nl, write('Yes.'), nl, continue(A);
    nl, write('No.'), nl, continue(A)).

```

```

check((when; past, simple, A; past, simple, B, Adverbial, Time), A) :-
    event(A,IdA), event(B,IdB), !,
    ((bcause(IdA, IdB); dominate(IdA,IdB)),
    check((simple, B, Adverbial, Time)),
    nl, write('Yes. '), nl, continue(A);
    nl, write('No. '), nl, continue(A)).

```

- follow-up questions are treated as if they were a main clause in a complex question containing the temporal focus as *when*-clause:

```

check((past, AnyAspect, A), B) :-
    check((when; past, simple, B; past, AnyAspect, A), B).
check((past, simple, A, Adverbial, Time), B) :-
    check((when; past, simple, B; past, simple, A, Adverbial, Time), B).

```

- in the case where a question is asked containing a *when*-clause containing an event that is different from the current temporal focus, the *when*-clause event becomes the new temporal focus and the old one is discarded:

```

check((when; past, simple, A; past, AnyAspect, B), C) :-
    check((when; past, simple, A; past, AnyAspect, B), A).
check((when; past, simple, A; past, simple, B, Adverbial, Time), C) :-
    check((past, simple, A; past, simple, B, Adverbial, Time), A).

```

In the program listed here there are quite a number of different check-procedures for *when*-clauses. Some of these could be collapsed together by having the parser produce a different and more structured representation of simple and complex questions. For ease of exposition, it was nevertheless decided to keep the notation used here.

3. The rules representing the aspectual network transitions:

- various ways of making a process, and associating times with it:
- basic definition for process:

```

process(IdA, Time1, Time2) :-
    occur(start(IdA), Time1),
    occur(stop(IdA), Time2).

```

- transition from culminated process to process requires the culmination point to be stripped off; the message indicates the required change:

```

process(IdA, Time1, Time2) :-
    occur(start(IdA), Time1),
    occur(cul(IdA), Time2),
    nl, write('Ignoring the culmination point. '), nl.

```

- a transition from culmination to process requires the addition of preparatory process:

```

process(IdA, Time1, Time2) :-
    occur(cul(IdA), Time2),           %restricting bcauses
    bcause(IdB, IdA),                 %to immediately preceding one;
    occur(any(IdB), Time1).

```

- a point can be turned into a process through iteration:


```
process(IdA, Time1, Time2) :-
    iterate(IdA, Time1, Time2).
```

- various ways of making a culminated process and associating times with it:
- basic definition involves the occurrence of a starting point and a culmination point:

```
cp(IdA, Time1, Time2) :-
    occur(start(IdA), Time1),
    occur(cul(IdA), Time2).
```

- if an extended event is found but no culmination point, this is signalled to the user:

```
cp(IdA, Time1, Time2) :-
    occur(start(IdA), Time1),
    occur(stop(IdA), Time2),
    nl, write('It is not known whether the event finished. '), nl.
```

- if only a culmination point is found, preparatory process has to be added, and this is signalled to the user:

```
cp(IdA, Time1, Time2) :-
    occur(cul(IdA), Time2),
    addprocess(IdA, IdB),
    occur(any(IdB), Time1),
    nl, write('Hmm, looking at the preparatory events here.').
```

- retrieving culminations from the database:

- the simple case:

```
cul(IdA, Time) :-
    occur(cul(IdA), Time); occur(point(IdA), Time).
```

- if expressions were squashed into a point they may be turned into culminations:

```
cul(IdA, Time) :-
    point(IdA, Time).
```

- if the event talked about only has a stop point associated with it, this is signalled to the user:

```
cul(IdA, Time) :-
    occur(stop(IdA), Time),
    nl, write('No real culmination point known. Verification fails.'),
    fail.
```

- points can be made by squashing any other event type, either an extended one (containing a start point), or a culmination:

```
point(IdA, Time) :-
    occur(start(IdA), Time),
    write('Event squashed into single blob.'), nl.
point(IdA, Time) :-
    occur(cul(IdA), Time).
```

4. And finally:

- adding preparatory process to a culmination by finding the preceding elements on the consequential chain:

```
addprocess(IdA, IdB) :-
    same_episode(IdB, IdA).
```

- iteration is handled by finding events that have the same event description but a different event identification; the associated times are ordered; the period of iteration is taken to last from Time1 (the earliest occurrence of an event of the right type) to Time2 (the latest occurrence of such an event):

```
iterate(IdA, Time1, Time2) :-
    event(A, IdA), point(IdA, TimeA),
    event(A, IdB), IdB == IdA, point(IdB, TimeB),
    event(A, IdC), IdC == IdB, IdC == IdA, point(IdC, TimeC),
    quicksort([TimeA, TimeB, TimeC], [Time1,X,Time2]),
    write('Yes. Repeatedly'), nl.
```

- the domination relation and the same_episode relation from the previous section:

```
dominate(IdA, IdB) :-
    dominate(IdA, IdX), !,
    same_episode(IdX, IdB).
same_episode(IdA, IdB) :-
    bcause(IdA, IdB).
same_episode(IdA, IdB) :-
    bcause(IdA, IdC),
    same_episode(IdC, IdB).
```

- and an obvious one:

```
occur(any(IdA), Time) :-
    occur(cul(IdA), Time);
    occur(start(IdA), Time);
    occur(stop(IdA), Time);
    occur(point(IdA), Time).
```

5. A short session with the program. Comments are given in italics:

| ?- start.

>> did mary reach the restaurant

No *no temporal focus had been established*

>> when mary visited maxies did mary reach the restaurant

Yes. *the required consequential link exists between the events*

>> did mary eat dinner

Yes. *Mary's visit to Maxies is still temporal focus*

>> did mary eat dinner for 30 minutes

Yes. *Mary's eating dinner is indeed a process of that length*

>> did mary eat dinner in 30 minutes

It is not known whether the event finished.

It is the right amount of time.

Yes. *Strictly speaking, the program should answer with a "no" since Mary's dinner did not culminate - or, more accurately, there is no information in the database that it culminated; a slightly more helpful answer is printed instead, but purely on the basis of knowledge of the aspectual nature of the events involved; no attempts are made to do helpful intention recognition*

>> did mary eat dinner in 25 minutes

It is not known whether the event finished.

No. *The program again notes that the event of Mary eating dinner is not of the appropriate aspectual type for the in-adverbial; moreover, the time-span asked about is not right either, so here the answer is definitely no*

>> when luke started the alarm did the police arrest luke

Yes.

>> had luke forced the door

Yes. *Luke starting the alarm is still temporal focus and is one of the consequences of Luke forcing the door*

>> was mary eating dinner

Yes. *Luke starting the alarm is still temporal focus and is temporally included in Mary's eating dinner; although Mary's dinner did not culminate, the progressive can still be used*

>> when john visited maxies did john eat dinner for 25 minutes

Ignoring the culmination point.

Yes. *The program has to determine whether there is a process of John eating dinner. It finds a complete nucleus and signals to the user that it can ignore the culmination point.*

>> when mary visited maxies did mary reach the restaurant in 60 minutes

Hmm, looking at the preparatory events here.

It is the right amount of time.

Yes. *The program searches for events on the same episode as Mary's reaching the restaurant and calculates whether the time they take up is the same as the time asked about in the adverbial*

8.5. Conclusion

It was argued in the previous chapters that the semantics of temporal expressions in language requires more structure on the domain underlying the meaning representations than is commonly assumed. Any ontology which treats the events talked about in a discourse as points or intervals on a time line or a set of time lines can be shown to be inherently inadequate and will

result in a semantics with a higher degree of complexity and ambiguity than is necessary.

Instead, an ontology was developed in which notions of contingency or consequentiality rather than pure sequentiality play a crucial role. It was shown how this ontology can be used to give a unified account of a wide number of temporal and aspectual constructions. It also accounts for the apparent ambiguities of *when* while still maintaining that this connective has a single sense. The organization of events under this contingent or consequential relation was also used to give an account of the structure of simple linear narrative.

From the survey of representation formalisms in this chapter, it emerged that similar ontological ideas have been around in the literature, most notably in the area of planning research. Using some of the techniques suggested in various temporal representation systems, an implementation of the consequential ontology was presented, and its use in a limited-coverage natural language system was demonstrated.

It was argued throughout the dissertation that any manageable logic or other formal system for natural language temporal descriptions will have to embody an ontology like the one developed here. An obvious next research step would be to try and develop such a formal system.

Another area where further research promises to be fruitful is in the examination of the anaphoric properties of tense. The starting point of the dissertation was that processing a discourse involves building and updating a structured representation of the states of affairs talked about. In chapter 6 it was shown how this event representation can be structured along the lines of the ontology developed here. The description given in that chapter of how a tensed clause can anaphorically refer to a previously introduced event does not constitute a complete solution to the problem of event reference. I think it nevertheless provides a framework in which further research into this can be carried out.

Finally, in the implementation offered here all the aspectual work was done in the database, none at the level of syntax. As was argued in chapter 7, however, some of the aspectual work could be carried out at an earlier stage in the processing. Further research is needed to determine what type of grammar would enable a limited form of aspectual classification at the level of syntax.

Also, in the implementation offered here, the inherent aspectual nature of an expression did not

play any role at all, the only thing taken into account being the aspectual characterization an event had been given in previous discourse. When one decides to build a system in which the grammar performs a limited amount of aspectual classification, it would have to be determined how important it is to be able to determine accurately the "basic" aspectual characterization of an expression. One expression whose temporal characteristics certainly need reconsidering is *to write a thesis*. Contrary to what one would expect, this seems to be a process expression rather than a culminated process: you never really finish writing a thesis; after a while you just stop.

References

- Ahn, I. and Snodgrass, R. (1986) Performance evaluation of a temporal database management system. In Zaniolo, C. (ed.) *Proceedings of ACM SIGMOD International Conference on Management of Data*, Association for Computing Machinery, Washington, DC, May, 1986, pp96-107.
- Allen, R. L. (1966) *The Verb System of Present-day American English*. The Hague: Mouton.
- Allen, J. F. (1981) Maintaining knowledge about temporal intervals. Technical Report No. 86, Department of Computer Science, Rochester University, 1981.
- Allen, J. F. (1984) Towards a general theory of action and time. *Artificial Intelligence*, 23, 123-154.
- Allen, J. F. and Hayes, P. J. (1985) A common-sense theory of time. In *Proceedings of the Ninth International Joint Conference on Artificial Intelligence*, University of California at Los Angeles, Los Angeles, Ca., August 18-23, 1985, pp528-531.
- Allen, J. F. and Kautz, H. A. (1985) A model of naive temporal reasoning. In Hobbs, J. R. and Moore, R. C. (eds.) *Formal Theories of the Commonsense World*, pp251-268. Norwood, N.J.: Ablex.
- Allen, J. F. and Koomen, J. A. (1983) Planning using a temporal world model. In *Proceedings of the Eighth International Joint Conference on Artificial Intelligence*, Karlsruhe, West Germany, August 8-12, 1983, pp741-747.
- Anderson, J. (1973) *An Essay Concerning Aspect*. The Hague: Mouton.
- Bach, E. (1981) On time, tense, and aspect: an essay in English metaphysics. In Cole, P. (ed.) *Radical Pragmatics*, pp63-81. New York: Academic Press.
- Bach, E. (1986) The algebra of events. *Linguistics and Philosophy*, 9, 5-16.
- Bache, C. (1982) Aspect and Aktionsart: towards a semantic distinction. *Journal of Linguistics*, 18, 57-72.
- Bartsch, R. (1983) Over de semantiek van nominalisaties. *GLOT*, 6, 1-29.
- Barwise, J. and Perry, J. (1983) *Situations and Attitudes*. Cambridge, Mass.: MIT Press.
- Bauer, G. (1970) The English 'perfect' reconsidered. *Journal of Linguistics*, 6, 189-198.
- Bauerle, R. (1979) Tense logics and natural language. *Synthese*, 40, 225-230.

- Bell, C. E. and Tate, A. (1985) Using temporal constraints to restrict search in a planner. Technical Report No. AIAI-TR-5, Artificial Intelligence Applications Institute, University of Edinburgh, Edinburgh, 1985.
- Bennett, M. and Partee, B. (1972) *Toward the Logic of Tense and Aspect in English*. Bloomington, Indiana: Indiana University Linguistics Club.
- Bennett, M. (1977) A guide to the logic of tense and aspect in english. *Logique et Analyse*, 20, 491-517.
- Bennett, M. (1981) Of tense and aspect: one analysis. In Tedeschi, P. and Zaenen, A. (eds.) *Syntax and Semantics*, Volume 14: *Tense and Aspect*, pp13-29. New York: Academic Press.
- van Benthem, J. (1983) *The Logic of Time*. Dordrecht: D. Reidel.
- Bolinger, D. (1971) The nominal in the progressive. *Linguistic Inquiry*, 2, 246-250.
- Carlson, G. (1977) A unified analysis of the English bare plural. *Linguistics and Philosophy*, 1, 413-457.
- Carlson, G. (1983) Thematic Roles and their Role in Semantic Interpretation. University of Trondheim, Working Papers in Linguistics.
- Carlson, L. (1981) Aspect and quantification. In Tedeschi, P. and Zaenen, A. (eds.) *Syntax and Semantics*, Volume 14: *Tense and Aspect*, pp31-64. New York: Academic Press.
- Charniak, E. and McDermott, D. (1985) *Introduction to Artificial Intelligence*. Reading, Mass.: Addison-Wesley.
- Chierchia, G. and Rooth, M. (1984) Configurational notions in Discourse Representation Theory. In Jones, C. and Sells, P. (eds.) *Proceedings of the Fourteenth Annual Meeting of the North Eastern Linguistics Society*, Graduate Linguistic Student Association, University of Massachusetts, Amherst, MA, March, 1984.
- Clifford, J. (1982) A logical framework for the temporal semantics and natural-language querying of historical databases. PhD Thesis, SUNY at Stonybrook.
- Clifford, J. and Warren, D. S. (1983) Formal semantics for time in databases. *ACM Transactions on Database Systems*, 8, 214-254.
- Comrie, B. (1976) *Aspect: An Introduction to the Study of Verbal Aspect and Related Problems*. Cambridge: Cambridge University Press.
- Comrie, B. (1985) *Tense*. Cambridge: Cambridge University Press.

- Cooper, R. (1985) Aspectual classes in Situation Semantics. Report No. CSLI-84-14C, Center for the Study of Language and Information, 1985.
- Copeland, G. (1982) What if mass storage were free?. *IEEE Computer*, 15, 27-35.
- Cresswell, M. (1974) Adverbs and events. *Synthese*, 28, 455-481.
- Dahl, O. (1975) Review of Verkuyl (1972). *Foundations of Language*, 12, 451-454.
- Dahl, O. (1981) On the definition of the telic-atelic (bounded-nonbounded) distinction. In Tedeschi, P. and Zaenen, A. (eds.) *Syntax and Semantics*, Volume 14: *Tense and Aspect*, pp79-90. New York: Academic Press.
- Dahl, O. (1985) *Tense and Aspect Systems*. Oxford: Basil Blackwell.
- Davidson, D. (1967) The logical form of action sentences. In Rescher, N. (ed.) *The Logic of Decision and Action*. Pittsburgh: University of Pittsburgh Press.
- Dean, T. L. and McDermott, D. V. (1987) Temporal data base management. *Artificial Intelligence*, 32, 1-55.
- Declerck, R. (1979) Aspect and the bounded/unbounded (telic/atelic) distinction. *Linguistics*, 17, 761-794.
- Dinsmore, J. (1982) The semantic nature of Reichenbach's tense system. *Glossa*, 16, 216-239.
- Dowty, D. (1972) Studies in the Logic of Verb Aspect and Time Reference. PhD Thesis, University of Texas.
- Dowty, D. (1979) *Word Meaning and Montague Grammar*. Dordrecht: D. Reidel.
- Dowty, D. R. (1982) Tenses, time adverbs and compositional semantics. *Linguistics and Philosophy*, 5, 23-55.
- Dowty, D. (1986) The effects of aspectual class on the temporal structure of discourse: semantics or pragmatics?. *Linguistics and Philosophy*, 9, 37-61.
- Drummond, M. (1984) Non-Linear Planning in Terms of Cause and Effect. Research Paper, Department of Artificial Intelligence, University of Edinburgh, Edinburgh, Scotland, July, 1984.
- Enc, M. (1981) Tense without Scope: an Analysis of Nouns as Indexicals. PhD Thesis, University of Wisconsin.
- Fikes, R. E., Hart, P. E. and Nilsson, N. J. (1972) Learning and executing generalised robot plans. *Artificial Intelligence*, 3.

- Freed, A. (1979) *The Semantics of English Aspectual Complementation*. Dordrecht: D. Reidel.
- Gabbay, D. and Moravcsik, J. (1980) Verbs, events, and the flow of time. In Rohrer, C. (ed.) *Time, Tense and Quantifiers*, pp59-83. Tübingen: Niemeyer.
- Galton, A. (1984) *The Logic of Aspect: An Axiomatic Approach*. Oxford: Clarendon Press.
- Garey, H. B. (1957) Verbal aspect in French. *Language*, 33, 91-110.
- Gazdar, G., Pullum, G. K. and Sag, I. A. (1982) Auxiliaries and related phenomena in a restrictive theory of grammar. *Language*, 58, 591-638.
- Guenther, S. (1984) Zur Repraesentation temporaler Beziehungen in SRL. Technical Report, Projektgruppe KIT, Fachbereich Informatik, Berlin: Technische Universitaet, 1984.
- Guenther, S., Habel, C. and Rollinger, C. (1983) Ereignisnetze: Zeitnetze und referentielle Netze. *Linguistische Berichte*, 88, 37-55.
- Halliday, M. A. K. (1980) On being teaching. In Greenbaum, S., Leech, G. and Svartvik, J. (eds.) *Studies in English Linguistics for Randolph Quirk*, pp61-64. London: Longman.
- Harlig, J. (1983) An appeal to the masses. In Chukerman, A., Marks, M. and Richardson, J. F. (eds.) *Papers from the Nineteenth Regional Meeting of the Chicago Linguistics Society*, Chicago, April 21-22, 1983, pp158-170.
- Harper, M. P. (1986) Time and Tense in English. Technical Report No. CS-86-14, Computer Science, Brown University, Providence, RI, July, 1986.
- Harper, M. P. and Charniak, E. (1986) Time and Tense in English. In *Proceedings of the 24th Annual Meeting of the Association for Computational Linguistics*, Columbia University, New York, N.Y., 10-13 June, 1986, pp3-9.
- Hayes, P. J. (1973) The frame problem and related problems in artificial intelligence. In Elithorn, A. and Jones, D. (eds.) *Artificial and Human Thinking*, pp45-59.
- Heinamaki, O. (1974) Semantics of English Temporal Connectives. PhD Thesis, University of Texas, Austin.
- Henry, F. (1982) Tense, aspect and time adverbials II. *Linguistics and Philosophy*, 5, 109-154.
- Hinrichs, E. (1983) The semantics of the English progressive: a study in Situation Semantics. In Chukerman, A., Marks, M. and Richardson, J. F. (eds.) *Papers from the Nineteenth Regional Meeting of the Chicago Linguistics Society*, Chicago, April 21-22, 1983, pp171-182.

- Hinrichs, E. (1985) A Compositional Semantics for Aktionsarten and NP Reference in English. PhD Thesis, Ohio State University. University Microfilms 85-26186.
- Hinrichs, E. (1986) Temporal anaphora in discourses of English. *Linguistics and Philosophy*, 9, 63-82.
- Hirschman, L. (1981a) An experiment in automated health care evaluation from narrative medical records. *Computers and Biomedical Research*, 14, 447-463.
- Hirschman, L. (1981b) Retrieving time information from natural language texts. In Oddy, R. (ed.) *Information Retrieval Research*, pp154-171.
- Hirschman, L. and Sager, N. (1981) Automatic information formatting of a medical sublanguage. In Kittredge, R. and Lehrberger, J. (eds.) *Sublanguage: Studies of Language in Restricted Semantic Domains*. Berlin: de Gruyter.
- Hirschman, L. and Story, G. (1981) Representing implicit and explicit time relations in narrative. In *Proceedings of the Seventh International Joint Conference on Artificial Intelligence*, University of British Columbia, Vancouver, B.C., Canada, August 24-28, 1981, pp289-295.
- Hirschman, L., Dahl, D., Dowding, J., Lang, F., Linebarger, M., Palmer, M., Riley, L. and Schiffman, R. (1987) The PUNDIT Natural Language Processing System. In Dahl, D., Dowding, J., Hirschman, L., Lang, F., Linebarger, M., Palmer, M., Passonneau, R. and Riley, L. (eds.) *Integrating Syntax, Semantics, and Discourse. DARPA Natural Language Understanding Program: R&D Status Report*. Paoli, Pa.: Unisys/Defense Systems.
- Hornstein, N. (1977) Towards a theory of tense. *Linguistic Inquiry*, 8, 521-557.
- Houweling, F. (1985) Deictic and anaphoric tense morphemes. In Cascio, V. L. and Vet, C. (eds.) *Temporal Structure in Sentence and Discourse*, pp161-190. Dordrecht: Foris Publications.
- Humberstone, L. (1979) Interval semantics for tense logic: some remarks. *Journal of Philosophical Logic*, 8, 171-196.
- Hurtig, R. R. (1974) The Relation of Linguistic Tense and Psychological Time. PhD Thesis, Columbia University.
- Inoue, K. (1979) An analysis of the English present perfect. *Linguistics*, 17, 221/222, 561-590.
- Isard, S. D. (1974) What would you have done if *Theoretical Linguistics*, 1, 233-255.
- Isard, S. D. (1975) Changing the context. In Keenan, E. (ed.) *Formal Semantics of Natural Language*. Cambridge: Cambridge University Press.

- Isard, S. D. and Longuet-Higgins, C. (1971) Modal tic-tac-toe. In Bogdan, R. J. and Niiniluoto, I. (eds.) *Logic, Language and Probability*. Dordrecht: D. Reidel.
- Jespersen, O. (1924) *Philosophy of grammar*. London: George Allen and Unwin.
- Johnson, M. R. (1981) A unified temporal theory of tense and aspect. In Tedeschi, P. and Zaenen, A. (eds.) *Tense and Aspect*, Volume 14, pp145-175. New York: Academic Press.
- Joos, M. (1964) *The English Verb: Form and Meaning*. Madison: University of Wisconsin Press.
- Kamp, J. A. W. (1971) Formal properties of 'Now'. *Theoria*, 37, 227-273.
- Kamp, H. (1979) Events, instants and temporal reference. In Bauerle, R., Egli, U. and von Stechow, A. (eds.) *Semantics from different points of view*, pp376-417. Berlin: de Gruyter.
- Kamp, H. (1980) Some remarks on the logic of change, part I. In Rohrer, C. (ed.) *Time, Tense and Quantifiers*, pp135-179. Tübingen: Niemeyer.
- Kamp, H. (1981a) A theory of truth and semantic representation. In Groenendijk, J. A. G., Janssen, T. M. V. and Stokhof, M. B. J. (eds.) *Formal Methods in the Study of Language*, Volume 136, pp277-322. Amsterdam: Mathematical Centre Tracts.
- Kamp, H. (1981b) Evenements, representations discursives et reference temporelle. *Langages*, 64, 39-64.
- Kamp, H. and Rohrer, C. (1983) Tense in texts. In Bauerle, R., Schwarze, C. and von Stechow, A. (eds.) *Meaning, Use and Interpretation of Language*, pp250-269. Berlin: de Gruyter.
- Kautz, H. and Allen, J. F. (1986) Generalized plan recognition. In *Proceedings of the 5th Annual Meeting of the American Association for Artificial Intelligence*, Philadelphia, Pa., 1986, pp32-37.
- Kenny, A. (1963) *Action, Emotion and Will*. London: Routledge and Kegan Paul.
- Klein, H. G. (1974) *Tempus, Aspekt, Aktionsart*. Tübingen: Niemeyer.
- Kowalski, R. A. (1979) *Logic for Problem Solving*. Amsterdam: North Holland.
- Kowalski, R. and Sergot, M. (1986) A logic-based calculus of events. *New Generation Computing*, 4, 67-95.
- Kuhn, S. (1979) The pragmatics of tense. *Synthese*, 40, 231-263.

- Lansky, A. L. (1985) Behavioral Specification and Planning for Multiagent Domains. Technical Report No. 360, Artificial Intelligence Center, SRI International, Menlo Park, Ca., 1985.
- Lansky, A. L. (1986) A representation of parallel activity based on events, structure, and causality. In *Workshop on Planning and Reasoning about Action*, Timberline Lodge, Mount Hood, Oregon, 1986, pp50-86.
- Lansky, A. L. and Owicki, S. S. (1983) GEM: a tool for concurrency specification and verification. In *Proceedings of the Second Annual ACM Symposium on Principles of Distributed Computing*, August, 1983, pp198-212.
- Lee, R. M., Coelho, H. and Cotta, C. (1985) Temporal inferencing on administrative databases. *International Journal for Information Systems*, 10, 197-206.
- Leech, G. N. (1971) *Meaning and the English Verb*. London: Longman.
- Link, G. (1983) The logical analysis of plurals and mass terms: a lattice-theoretical approach. In Bauerle, R., Schwarze, C. and von Stechow, A. (eds.) *Meaning, Use and Interpretation of Language*, pp302-323. Berlin: de Gruyter.
- Lyons, J. (1968) *Introduction to Theoretical Linguistics*. Cambridge: Cambridge University Press.
- Lyons, J. (1977) *Semantics*. Cambridge: Cambridge University Press.
- Lyons, J. (1982) Deixis and subjectivity: Loquor, ergo sum?. In Jarvella, R. and Klein, W. (eds.) *Speech, place and action.*, pp101-124. Chichester: John Wiley and Sons.
- Lys, F. and Mommer, K. (1986) The problem of aspectual verb classification. In Farley, A. M., Farley, P. T. and McCullough, K. (eds.) *Papers from the General Session at the Twenty-Second Regional Meeting of the Chicago Linguistic Society*, Chicago, April 17-19, 1986, pp216-230.
- McCarthy, J. and Hayes, P. J. (1969) Some philosophical problems from the standpoint of artificial intelligence. In Meltzer, B. and Michie, D. (eds.) *Machine Intelligence*, Volume 4, pp463-502. Edinburgh: Edinburgh University Press.
- McCawley, J. D. (1971) Tense and time reference in English. In Fillmore, C. and Langendoen, T. (eds.) *Studies in Linguistic Semantics*, pp96-113. New York: Holt, Rinehart and Winston.
- McCawley, J. D. (1981) Notes on the English present perfect. *Australian Journal of Linguistics*, 1, 81-90.
- McCoard, R. (1978) *The English Perfect: Tense Choice and Pragmatic Inferences*. Amsterdam: North Holland.

- McDermott, D. (1982) A temporal logic for reasoning about processes and plans. *Cognitive Science*, 6, 101-155.
- Marsh, E. and Friedman, C. (1985) Transporting the Linguistic String Project system from a medical to a navy domain. *ACM Transactions on Office Information Systems*, 3, 121-140.
- ter Meulen, A. G. B. (1982) The representation of time in natural language. In ter Meulen, A. G. B. (ed.) *Studies in Model-Theoretic Semantics*, pp177-191. Dordrecht: Foris Publications.
- ter Meulen, A. G. B. (1984) Events, quantities and individuals. In Landman, F. and Veltman, F. (eds.) *Varieties of Formal Semantics*, pp259-279. Dordrecht: Foris Publications. Proceedings of the 4th Amsterdam Colloquium, September 1982.
- Miller, G. A. and Johnson-Laird, P. N. (1976) *Language and Perception*. Cambridge: Cambridge University Press.
- Mittwoch, A. (1980) The grammar of duration. *Studies in Language*, 4, 201-227.
- Mittwoch, A. (1982) On the difference between *Eating* and *Eating Something*: activities versus accomplishments. *Linguistic Inquiry*, 13, 113-121.
- Moens, M. and Steedman, M. (1987) Temporal Ontology and Temporal Reference. Forthcoming.
- Montague, R. (1973) The proper treatment of quantification in ordinary English. In Hintikka, J., Moravcsik, J. M. E. and Suppes, P. (eds.) *Approaches to Natural Language*. Dordrecht: D. Reidel. Reprinted in R H Thomason (ed.) (1974), *Formal Philosophy: Selected Papers of Richard Montague*, pp247-270. Yale University Press: New Haven, Conn.
- Mourelatos, A. (1981) Events, processes and states. In Tedeschi, P. and Zaenen, A. (eds.) *Syntax and Semantics*, Volume 14: *Tense and Aspect*, pp191-212. New York: Academic Press.
- Nerbonne, J. (1984) German Temporal Semantics. Working Papers in Linguistics No. 30, Linguistics, Ohio State University, Columbus, Ohio, 1984.
- Nerbonne, J. (1986) Reference time in narration. *Linguistics and Philosophy*, 9, 83-95.
- Nordenfelt, L. (1977) *Events, Actions and Ordinary Language*. Lund: Doxa.
- Oberlander, J. R. (1987) The Semantics of Temporal Indexicals. PhD Thesis.
- Parsons, T. (1982) Review of Dowty (1979). *Philosophical Review*, 91, 290-295.

- Parsons, T. (1984) Underlying events in the logical analysis of English. Paper read the the Conference on the Philosophy of Donald Davidson, Rutgers University, Spring 1984.
- Partee, B. (1973) Some structural analogies between tenses and pronouns in English. *Journal of Philosophy*, 70, 601-609.
- Partee, B. H. (1984) Nominal and temporal anaphora. *Linguistics and Philosophy*, 7, 243-286.
- Passonneau, R. J. (1987) A computational model of the semantics of tense and aspect. In Dahl, D., Dowding, J., Hirschman, L., Lang, F., Linebarger, M., Palmer, M., Passonneau, R. and Riley, L. (eds.) *Integrating Syntax, Semantics, and Discourse. DARPA Natural Language Understanding Program: R&D Status Report*. Paoli, Pa.: Unisys/Defense Systems.
- Pelletier, J. (ed.) (1979) *Mass Terms: some Philosophical Problems*. Dordrecht: D. Reidel.
- Platzack, C. (1979) *The Semantic Interpretation of Aspect and Aktionsarten: a Study of Internal Time Reference in Swedish*. Dordrecht: Foris Publications.
- Potts, T. C. (1965) States, activities and performances. *Aristotelian Society Supplementary Volume*, 39, 65-84.
- Prior, A. N. (1967) *Past, Present and Future*. Oxford: Clarendon Press.
- Pulman, S. (1987) Events and VP modifiers. In *Proceedings of the Alvey News Sponsored Workshop on Formal Semantics in Natural Language Processing*, University of Essex, March, 1987.
- Quine, W. V. (1960) *Word and Object*. Cambridge, Mass.: MIT Press.
- Quirk, R., Greenbaum, S., Leech, G. and Svartvik, J. (1972) *A Grammar of Contemporary English*. London: Longman.
- Quirk, R., Greenbaum, S., Leech, G. and Svartvik, J. (1985) *A Comprehensive Grammar of the English Language*. London: Longman.
- Reichenbach, H. (1947) *Elements of Symbolic Logic*. London: Macmillan.
- Rescher, J. and Urquhart, A. (1971) *Temporal Logic*. Berlin: Springer-Verlag.
- Reyle, U. (1986) Zeit und Aspekt bei der Verarbeitung natuerlicher Sprachen. PhD Thesis, Institute for Romance Linguistics, University of Stuttgart.
- Richards, B. (1982) Tense, aspect and time adverbials I. *Linguistics and Philosophy*, 5, 59-107.

- Richards, B. (1986) Tenses, temporal quantifiers and oblique contexts. In Lepore, E. (ed.) *The Philosophy of Donald Davidson: A Perspective on Inquiries into Truth and Interpretation*. Oxford: Basil Blackwell.
- Richards, B. (1987) Temporal connection. In and Oberlander, J. (eds.) *Temporal Reference and Quantification: an IQ Perspective*, pp98-113. Edinburgh: Centre for Cognitive Science.
- Ritchie, G. D. (1979) Temporal Clauses in English. *Theoretical Linguistics*, 6, 87-115.
- Sadri, F. (1985) Plan-formation using a calculus of events. Technical Report, Imperial College, January, 1985.
- Sadri, F. (1986) Representing and reasoning about time and events: 3 recent approaches. Technical Report, Imperial College, January, 1986.
- Sag, I. (1973) On the state of progress on progressives and statives. In Bailey, C. and Shuy, R. (eds.) *New Ways of Analyzing Variation in English*, pp83-95. Washington: Georgetown University Press.
- Scott, D. (1968) Advice on Modal Logic. In Lambert (ed.) *Philosophical Problems in Logic*. Dordrecht: D. Reidel.
- Smith, C. S. (1983) States and dynamics. *Language*, 59, 479-502.
- Snodgrass, R. and Ahn, I. (1986) Temporal databases. *IEEE Computer*, 19, 35-42.
- Steedman, M. J. (1977) Verbs, time and modality. *Cognitive Science*, 1, 216-234.
- Steedman, M. (1981) The nature of temporal reference explains the variety of tenses, aspects and time adverbials. Paper presented at the Sloan Workshop, Ohio State University.
- Steedman, M. J. (1982) Reference to past time. In Jarvella, R. and Klein, W. (eds.) *Speech, Place and Action*, pp125-157. New York: John Wiley and Sons.
- Steedman, M. J. (1986) Incremental Interpretation in Dialogue. ACORD Deliverable 2.4, Centre for Cognitive Science, Edinburgh.
- Taylor, B. (1977) Tense and continuity. *Linguistics and Philosophy*, 1, 199-220.
- Thomson, A. and Martinet, A. (1974) *A Practical English Grammar*. Oxford: Oxford University Press.
- Tichy, P. (1980) The logic of temporal discourse. *Linguistics and Philosophy*, 3, 343-369.
- Tichy, P. (1980) The semantics of episodic verbs. *Theoretical Linguistics*, 7, 263-296.

- Tichy, P. (1985) Do we need interval semantics? *Linguistics and Philosophy*, 8, 263-282.
- Turner, R. (1984) *Logics for Artificial Intelligence*. Chichester: Ellis Horwood.
- Vendler, Z. (1967) Verbs and times. Chapter 4 in *Linguistics in Philosophy*, pp97-121. Ithaca, N.Y.: Cornell University Press.
- Vere, S. A. (1981) Planning in Time: Windows and Durations for Activities and Goals. Technical Report, Jet Propulsion Lab, Pasadena, Ca., 1981.
- Vere, S. (1984) Temporal Scope of Assertions and Window Cutoff. Technical Report, Jet Propulsion Laboratory, Pasadena, Ca., November, 1984.
- Verkuyl, H. J. (1972) *On the Compositional Nature of the Aspects*. Dordrecht: D. Reidel.
- Vilain, M. B. (1982) A system for reasoning about time. In *Proceedings of the National Conference on Artificial Intelligence*, Pittsburgh, Pa., 1982, pp197-201.
- Vilain, M. and Kautz, H. (1986) Constraint propagation for temporal reasoning. In *Proceedings of the 5th Annual Meeting of the American Association for Artificial Intelligence*, Philadelphia, Pa., 1986, pp377-382.
- Vlach, F. (1981a) The semantics of the progressive. In Tedeschi, P. and Zaenen, A. (eds.) *Syntax and Semantics*, Volume 14: *Tense and Aspect*, pp271-292. New York: Academic Press.
- Vlach, F. (1981b) La semantique du temps et de l'aspect en anglais. *Langages*, 15, 65-79.
- de Vuyst, J. (1983) Situation-descriptions: temporal and aspectual semantics. In ter Meulen, A. G. B. (ed.) *Studies in Model-Theoretic Semantics*, pp161-176. Dordrecht: Foris Publications.
- Waldinger, R. (1977) Achieving several goals simultaneously. In Elcock, E. and Michie, D. (eds.) *Machine Intelligence*, Volume 8, pp94-136. Chichester: Ellis Horwood.
- Webber, B. L. (1978) On deriving aspectual sense. *Cognitive Science*, 2, 385-390.
- Webber, B. L. (1987) Two Steps Closer to Event Reference. Technical Report No. MS-CIS-86-75, Department of Computer and Information Science, Moore School, University of Pennsylvania, Philadelphia, Pa., February, 1987.
- Wong, H. K. T. and Mylopoulos, J. (1977) Two views of data semantics: a survey of data models in Artificial Intelligence and database management. *Infor*, 15, 344-383.
- Woods, W. A. (1984) Natural language communication with machines: an ongoing goal. In Reitman, W. (ed.) *Artificial Intelligence Applications for Business: Proceedings of the NYU Symposium, May 1983*, pp195-209. Norwood, N.J.: Ablex.